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Open File Report 6123

Geology and Mineral Potential of the Paleoproterozoic River Valley Intrusion and Related Rocks, Grenville Province

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ONTARIO GEOLOGICAL SURVEY

Open File Report 6123

Geology and Mineral Potential of the Paleoproterozoic River Valley Intrusion and Related Rocks, Grenville Province

by

R.M. Easton

2003

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Abstract

Rocks of the East Bull Lake intrusive suite, located in the Southern and Grenville provinces of the Canadian Shield, have been the subject of intensive exploration for copper, nickel and platinum group elements since the fall of 1998. Apart from reconnaissance-scale mapping conducted in 1971, rocks of this suite present in the Grenville Province were poorly known. This report summarizes the results of 4 different Ontario Geological Survey projects active between 1999 and 2003 that focussed on these rocks. The study examined East Bull Lake intrusive suite rocks located in Crerar, Dana, Henry, Loughrin and Street townships, an area located between Sudbury and the hamlet of River Valley, north of Highway 17 and south of the Grenville Front.

The East Bull Lake intrusive suite consists of 3 major, and several smaller, mafic layered igneous intrusions that occur along an east-northeast trend, over a distance of ~250 km, roughly centered on the present site of the Sudbury Igneous Complex. In earliest Paleoproterozoic time, an interpreted mantle-plume centered on Sudbury gave rise to plutonism (East Bull Lake intrusive suite) and volcanism (Elliot Lake Group). Rock types in the intrusions range in composition from anorthosite to melanorite, troctolite and rarely peridotite. Leucogabbronorite and gabbronorite are the dominant varieties. The crystallization order of primocryst phases is most commonly plagioclase (An_{80-62}), olivine (Fo_{76-59}), orthopyroxene (En_{75-58}), titanomagnetite, and clinopyroxene. Phase layering in the intrusions varies from centimetre and metre-scale, which is discernible in outcrop, and decametre or larger, which is identified by detailed mapping. Isomodal layering is most common; mineral- and size-graded layers are less common. Cryptic layering is well documented for the River Valley intrusion.

Metamorphism associated with the Penokean Orogeny (1870 to 1820 Ma) formed greenschist or amphibolite facies mineral assemblages in intrusions in the Southern Province. Intrusions in the Grenville Province locally exhibit primary mineralogy and well-preserved igneous textures, although they were subjected to upper amphibolite facies regional metamorphism, at roughly 1040 to 995 Ma, during the Grenville Orogeny. Many of the East Bull Lake intrusive suite rocks in the study area are gneissic, particularly those in the western half. In addition, some intrusions in the Grenville Province are spatially, and possibly genetically, linked with a suite of orthopyroxene hornblendite bodies which occur at, or near, the basal contact of these bodies.

At least 5 main bodies of East Bull Lake intrusive suite rocks are present in the study area. The largest of these is the River Valley intrusion, which covers an area of roughly 100 km^2. Other bodies include the Loughrin Lake, Third Concession and Contact intrusions as well as the Street metagabbro; these range in size from 5 to 25 km^2.

The northern boundary of the study area coincides with the Grenville Front, and the entire study area lies within the Grenville Front tectonic zone. Host rocks to the intrusions can be grouped into several distinct gneiss associations of Archean, Proterozoic, and mixed Archean and Proterozoic age. From northwest to southeast these are the Front, Street, Crerar and Pardo gneiss associations and the Red Cedar Lake gneiss. Most of the gneissic rocks in the study area are migmatitic. Several Geon 24 to 23 felsic intrusions cut rocks of the Street gneiss association and the East Bull Lake intrusive suite within the study area. In addition, several dike swarms are present within the study area, including the Matachewan, Sudbury, and Grenville diabase dike swarms, all of which cut East Bull Lake intrusive suite rocks in the study area.

The River Valley intrusion is hosted solely in Archean rocks belonging to the Crerar and Pardo gneiss associations and the Red Cedar Lake gneiss. The Street gneiss association hosts the Loughrin Lake, Third Concession and Contact intrusions, and the Street metagabbro. The 5 main bodies described above are thought to be separate and distinct intrusions, based on the fact that they are hosted by different country rock sequences and because of differences in rock types and geochemistry between individual bodies. This interpretation differs from earlier work which suggested that all East Bull Lake intrusive suite rocks in the study area belonged to the River Valley intrusion.

A stratigraphic section has only been defined for the River Valley intrusion, varying from a partly preserved section in the north (~0.8 km thick) to a more complete section (1.4 km) in the south. The Loughrin Lake intrusion may contain roughly 500 to 1000 m of stratigraphy. Both the thickness and rock types in these measured sections are comparable to those observed in East Bull Lake suite intrusions present in the Southern Province.

Pearce-element ratio diagrams and chondrite-normalized rare earth element plots illustrate that each of main East Bull Lake intrusive suite bodies formed from one or more cogenetic magmas. A high-Al (17 to 19 wt. %), low Ti (~0.5 wt. %) tholeiite composition can explain the dominant leucocratic rock compositions in the Southern Province intrusions. A related, but more olivine-rich magma is needed to explain the Olivine Gabbronorite zone rocks in the Southern Province and the River Valley intrusions. In the case of the River Valley intrusion, it is not known if more than one magma type is present. An olivine-rich, high-Al, low-Ti tholeiite can explain the evolution of the Olivine Gabbronorite and stratigraphically higher zones, however, the existence of a boninitic magma (MgO ~13.5 wt. %, Al_2O_3 ~13.5 wt. %, SiO_2 ~52 wt. %) may be necessary to explain the parent magma composition for the mineralized, marginal, parts of this intrusion. Both parental magma types contained high platinum-group element concentrations (10 to 50 ppb Pt+Pd+Au).

Contact-type copper, palladium, platinum, rhodium mineralization (1 to 10 g/t Pd+Pt+Au) occurs in the matrix of an inclusion- and/or fragment-bearing gabbronorite to leucogabbronorite at the base or side of the River Valley intrusion where the igneous contact is preserved. A second, similar, zone of mineralization may occur 100-200 m higher in the stratigraphy. Chalcopyrite and lesser pyrrhotite form 1-3% sulphide, either finely disseminated or as local centimetre-size patches. Reef-type mineralization has yet to be recognized within the River Valley intrusion. Detailed study of the East Bull Lake suite intrusions suggests that the mineralization originates from the injection and subsequent dynamic mixing of a S-saturated, inclusion-bearing, second-stage, platinum-group element-enriched (20-100 ppb) magma that entered the magma chamber carrying liquid sulphide droplets.

Mineral exploration for copper, nickel and platinum group elements in the study area should focus on East Bull Lake intrusive suite bodies that exhibit a well-defined stratigraphy containing a variety of mafic rock types, as well as areas where primary intrusive contacts are preserved. Other mineral deposits in the study area include building and crushed stone within East Bull Lake intrusive suite rocks, Geon 24 to 23 felsic intrusions, and Sudbury diabase dikes. Country rock units locally host large and abundant garnets that have been investigated as industrial minerals.

Geology and Mineral Potential of the Paleoproterozoic River Valley Intrusion and Related Rocks, Grenville Province

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Ontario Geological Survey
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2003

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Ministry of Northern Development and Mines, Sudbury, Ontario, Canada, P3E 6B5

Introduction

The Paleoproterozoic River Valley intrusion, located about 45 km east-northeast of Sudbury, Ontario, covers an area of roughly 100 km^2 within the Grenville Province immediately south of the Grenville Front (Figure 1). Apart from regional mapping of the body conducted in 1970 and 1971 by the Ontario Department of Mines (Lumbers 1971, 1973), little was known about the internal geology, stratigraphy, mineralogy, geochemistry and geological history of the intrusion. Prior to 1998, the relationship of the River Valley intrusion with the East Bull Lake and Agnew Lake intrusions—located in the Southern Province west of Sudbury—was uncertain, although it seemed likely that the River Valley intrusion was correlative with these other bodies. Beginning in the summer of 1998, however, the East Bull Lake, Agnew Lake and the River Valley intrusions have all been the subject of ongoing copper-nickel-platinum group element (PGE) mineral exploration. This exploration interest increased the need for learning more about the River Valley intrusion, and its relationship to other Paleoproterozoic mafic intrusions in the Southern Province. Consequently, as reported herein, several Ontario Geological Survey projects were initiated between 1998 and 2002 in order to address these fundamental questions about the River Valley intrusion.

The main purpose of these projects was to better understand the setting, distribution, form and composition of the River Valley intrusion, its relationship to the other Paleoproterozoic mafic intrusions, and its platinum group element potential. This purpose was achieved by accomplishing the objectives listed below:

1. Generating detailed geological maps of the River Valley intrusion (Easton and Hrominchuk 2001a, 2001b; Easton 2001; Easton and terMeer in prep.).
2. Describing the geology, rock types, stratigraphy, and structure of the River Valley intrusion (Hrominchuk 1999, 2000; James et al. 2002a, 2002b).
3. Describing and analysing the geochemistry of the River Valley intrusion (Easton and Hrominchuk 2002; Hrominchuk 2000; James et al. 2002a, 2002b).
4. Using the geology, stratigraphy, petrography, structure, geochemistry and mineralization to interpret the petrogenesis of the River Valley intrusion (Hrominchuk 2000; James et al. 2002a, 2002b).
5. Making comparisons with other East Bull Lake suite intrusions in order to facilitate the understanding of this large Paleoproterozoic magmatic province (James et al. 2002a, 2002b).

In addition, these studies have led to a better understanding of the host rocks to the River Valley intrusion in this part of the Grenville Province, and to the tectonic framework of the Sudbury area (Easton 2000, 2002b), as described in the section on "Country Rocks" in this report.

This report consists of two main sections. The first section briefly describes the "Country Rocks" to the East Bull Lake intrusive suite bodies located in the Grenville Province east of Sudbury, with an emphasis on those aspects of the geology that have a bearing on the emplacement and subsequent tectonic history of the mafic intrusive rocks. The second part on the "East Bull Lake Intrusive Suite" describes the geology, geochemistry and mineral potential of these igneous rocks in the Grenville Province, with an emphasis on the River Valley intrusion.

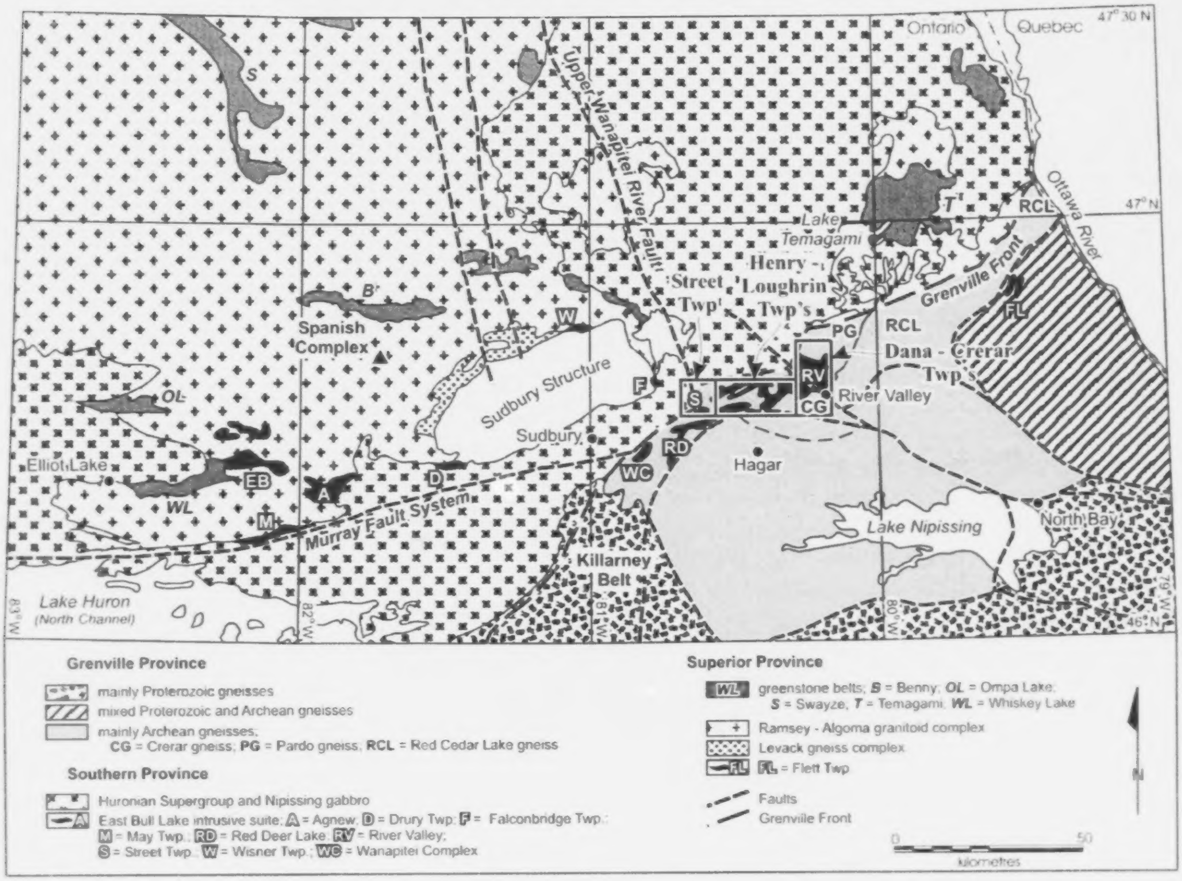

Ontario
Quebec
47°30'N
47°N
46°N
83°W
82°W
81°W
80°W
79°W
S
B
OL
WL
T
Spanish Complex
Elliot Lake
EB
A
M
D
W
F
S
RV
CG
RD
WC
FL
Upper Wanapitei River Fault
Lake Temagami
Henry - Loughrin Twp's
Street Twp
PG
RCL
Dana - Crerar Twp's
Grenville Front
Ottawa River
River Valley
Sudbury Structure
Sudbury
Hagar
Murray Fault System
Killarney Belt
Lake Nipissing
North Bay
Lake Huron
(North Channel)
Grenville Province
mainly Proterozoic gneisses
mixed Proterozoic and Archean gneisses
mainly Archean gneisses; CG = Crerar gneiss; PG = Pardo gneiss; RCL = Red Cedar Lake gneiss
Southern Province
Huronian Supergroup and Nipissing gabbro
East Bull Lake intrusive suite; A = Agnew; D = Drury Twp; F = Falconbridge Twp.; M = May Twp.; RD = Red Deer Lake; RV = River Valley; S = Street Twp.; W = Wisner Twp.; WC = Wanapitei Complex
Superior Province
greenstone belts; B = Benny; OL = Ompa Lake; S = Swayze; T = Temagami; WL = Whiskey Lake
Ramsey - Algoma granitoid complex
Levack gneiss complex
FL = Flett Twp
Faults
Grenville Front
N
0
50
kilometres

Figure 1. Location map showing the location of the study area, the distribution of Archean rocks in the south-central Canadian Shield in Ontario, and the distribution of rocks of the East Bull Lake intrusive suite.

ACCESS

Access is provided by several main roads that join with Highway 17 (Trans-Canada Highway), which runs easterly to the south of the study area. These include the following:

1. Kukagami Lake road, located roughly 10 km east of the community of Wahnapitae, that extends north through central Street Township,
2. North road, which extends north from Markstay to the Grenville Front near Crerar, and which is located about 500 m east of the Street-Loughrin township boundary,
3. Highway 535 and the Boundary road, which extend north from Hagar to the Grenville Front along the Loughrin-Henry township boundary,
4. Highway 539 which extends north from Warren to the hamlet of River Valley, and
5. Highway 805, which extends west from River Valley along the Sturgeon River to Glen Afton, then north along the western boundary of Dana Township.

Numerous secondary and logging roads, of varied vintage and quality, branch off of the main access roads and provide reasonable access to most of the study area. Areas that are difficult to access include central Loughrin Township, Crerar Township south of the Sturgeon River, and northern Dana Township north of the River Valley intrusion. Along the Grenville Front, access is also provided by an abandoned Canadian National Railway right-of-way that parallels the Kabikotitwia and Sturgeon rivers. The study area contains few lakes of any size; those that are present are generally not accessible by road or trail and thus provide no water access. The Sturgeon River channel is cut into a thick sequence of glaciolacustrine and glaciofluvial sediments, and within the study area, provides few exposures of bedrock.

PHYSIOGRAPHY

Relief in the study area is generally less than 150 m, ranging from roughly 220 m above sea level along the Sturgeon River to about 325 m above sea level in northeast Henry, northwest Crerar, and central and western Dana townships. Throughout much of the study area, outcrops in areas underlain by country rocks are generally steep-sided, rising 3 to 30 m above the surrounding topography. Areas underlain by rocks of the East Bull Lake intrusive suite, particularly where these rocks are little deformed, form large, flat-topped hills that are commonly steep-sided on the west and north sides (Photo 1). These hills rise between 50 and 80 m above the surrounding countryside. Most outcrop of East Bull Lake intrusive suite rocks occurs in these hills, with minimal exposure in the intervening low areas.

Photo 1. View westward from station 99RME-0462 in Crerar Township, showing typical topography within the study area. Large hills contain well-preserved River Valley rocks, whereas low areas are poorer in outcrop and contain recrystallized to gneissic River Valley rocks.

Distribution of outcrop is varied. Exposure is abundant (50% to 70%) in areas of Street Township underlain by gneisses of the Grenville Province, as well as in the parts of northern Crerar and central and western Dana townships that are underlain by rocks of the River Valley intrusion. In the eastern and central parts of Street Township, outcrop areas are only thinly covered and vegetated, likely reflecting past effects of fume kill from the Coniston and Falconbridge smelting operations, which lie upwind of the township (*see also* distribution of Cu, Pt, Pd in humus in Tardif 2000). In contrast, areas distal to these operations, such as Loughrin and Henry townships, show a marked increase in both lichen and forest cover. In addition, the tops of large hills in areas underlain by rocks of the East Bull Lake intrusive suite are generally only thinly covered and vegetated. Outcrop is also abundant (40-50% exposure) in northwest Loughrin Township. Outcrop is least abundant in southern Crerar, Henry and Loughrin townships (<15% exposure). In general, outcrop is more abundant in areas underlain by rocks of the East Bull Lake intrusive suite than in those areas underlain by country rock.

PREVIOUS GEOLOGICAL INVESTIGATIONS

Although proximal to Sudbury and including rocks of the Southern Province, the study area was not subjected to previous detailed geological investigation, even though adjacent townships to the west and north have had a long history of geological study. Murray (1857) navigated and mapped the Sturgeon River, and assigned the rocks exposed along the river in the study area to the Laurentian series. Although Murray (1857) did not describe any rocks of the River Valley intrusion, he did observe the presence of chlorite in rocks along the trace of the Grenville Front between Glen Afton and Crerar. Collins (1913) briefly described the character of rocks located near the present Southern–Grenville province boundary in Street Township. Fairbairn (1939) mapped the area southeast of Wanapitei Lake, including parts of Loughrin and Street townships at 1:31 680 scale, but did not subdivide rocks within what is now known as the Grenville Province. He did, however, recognize the presence of metaconglomerate within the Grenville Province in the Timmins Creek and Jones Lake areas. Kindle (1933), as part of a regional mapping project in the Wanapitei Lake area, described 4 mineral occurrences located in Street Township. Thomson (1961) and Thomson and Card (1963), in their study of Davis, Kelley, Maclennan and Scadding townships, mapped some outcrops in northernmost Loughrin and Street townships. Dressler (1979) mapped rocks south of the Grenville Front within Janes Township.

The study area was included in Lumbers' (1973) 1:63 360 scale map of the Sudbury–River Valley area. Most significantly, Lumbers (1973) noted the presence of Huronian metavolcanic rocks in the Timmins Creek area along the Grenville Front. Grant et al. (1962) described kyanite-bearing gneiss and associated paragneiss in Dryden Township; equivalents of these rocks strike into Street and Loughrin townships. The study area was included in the area studied by Tardif (2000) and Tardiff and Crabtree (2000) for platinum, palladium, gold and kimberlite indicator minerals in surficial materials.

The earliest reconnaissance mapping of the River Valley intrusion was by Bruce (1932), who mapped only the western third of Dana Township. Lumbers (1971, 1973) outlined the regional distribution of the River Valley intrusion and located the Grenville Front during reconnaissance mapping (1:63 360 scale) of the area between Sudbury and River Valley. Davidson (1986) produced a detailed map of a portion of the western margin of the River Valley intrusion north of the Sturgeon River and recognized the presence of abundant mylonite zones along the Grenville Front in that area. Ashwal and Wooden (1989) collected and analysed samples from the River Valley intrusion for Rb/Sr and Pb/Pb isotope work and obtained a Pb/Pb whole-rock age of 2562±165 Ma. Their report also included rock and petrography descriptions. A precise U/Pb zircon age of 2475+2/-1 Ma was obtained from a sample collected and analyzed by Larry Heaman of the University of Alberta from one of the two large quarries located in the intrusion in Dana Township, most likely the Erana quarry. This age has not been published in abstract or journal form; however, it is cited in the form of a personal communication in Easton, Davidson and Murphy (1999).

Prior to 1995, mineral exploration in the study area had focussed on industrial minerals, namely garnet (Lumbers 1971; Vos, Smith and Stevenato 1981; Easton and Murphy 2002 and references therein), feldspar (Vos, Smith and Stevenato 1981) and building stone (WIFCo and Dallaire 1985; Kirwan 1992; Sawitzky 1994; Positano 1995) (Appendix 1). In the 1960s, some exploration activity occurred in both Crerar and Dana townships for copper-nickel mineralization, focusing mainly on the Tomrose occurrence and near the site of the current Dana North property, as summarized in Lumbers (1971) and in Appendix 1. Subsequently, Dana Township was included in the Temagami Land Caution and was withdrawn from staking between 1972-1996.

During 1995, WMC International Ltd. conducted mapping and geophysical surveys over parts of Crerar, Henry, Loughrin and Street townships during a search for platinum group element and nickel-copper mineralization (Newman 1996). As part of the Operation Treasure Hunt program, proprietary airborne geophysical data collected by WMC International Ltd. in 1995 was released in March 2002 (Ontario Geological Survey 2002). Promising platinum-group element assay values from rocks of the River Valley intrusion near Dana Lake and Azen Creek were first reported by prospectors L. Luhta, R. Bailey and R. Orchard in November 1998. Subsequently, Pacific North West Capital Corporation and Mustang Minerals Corporation staked most of the River Valley intrusion in Crerar and Dana townships. Between 1998-2002, exploration for platinum group element and nickel-copper mineralization in the study area has been conducted mainly by Aquiline Resources Incorporated, Mustang Minerals Corporation, Pacific North West Capital Corporation, and Platinum Group Metals and their subcontractors (*see* summary in Appendix 1).

THIS STUDY

The geographic area covered by this report lies within National Topographic Sheets 41I/9 (Glen Afton) and 41I/10 (Capreol), and includes Crerar, Dana, Henry, Loughrin and Street townships (*see* Figures 1, 2). Because of the focus on rocks of the East Bull Lake intrusive suite and their contact relationships, minor work was also done in Awrey, Davis, Gibbons, Janes, Kelley and McWilliams townships. Wherever possible, observations are keyed to specific townships. In some instances, it is necessary to use the broader term "study area". In this report, study area means the area of the Grenville Province east of Sudbury that is bounded to the south by Highway 17, to the north by the Grenville Front, and to the west by the Kukagami Lake Road. The eastern boundary approximates the east boundary of Crerar and Dana townships (*see* Figures 1, 2).

This report serves as a summary of the results of 4 separate Ontario Geological Survey (OGS) projects related to mapping of the River Valley intrusion that were conducted between 1999 and 2002. Mapping of Crerar and Dana townships, which cover the eastern half of the River Valley intrusion, was conducted at 1:20 000 scale in 1999 by R.M. Easton and J.L. Hrominchuk (OGS Project Number 99-007; Easton and Hrominchuk 1999, 2001a, 2001b). This work subsequently led to compilation of the Glen Afton National Topographic Map Sheet (NTS 41I/09) by R.M. Easton at 1:50 000 scale in 2001 (OGS Project Number 01-009; Easton 2001). Mapping of Henry and Loughrin townships, which cover the western half of the River Valley intrusion, was conducted at 1:20 000 and 1:50 000 scale in 2002 by R.M. Easton (OGS Project Number 02-008; Easton 2002b). Because of the unique nature of this project, in that it involved several researchers working at different times over a 4-year period, Table 1 is presented in order to provide an overview of the specific contributions made by the different researchers involved in the project.

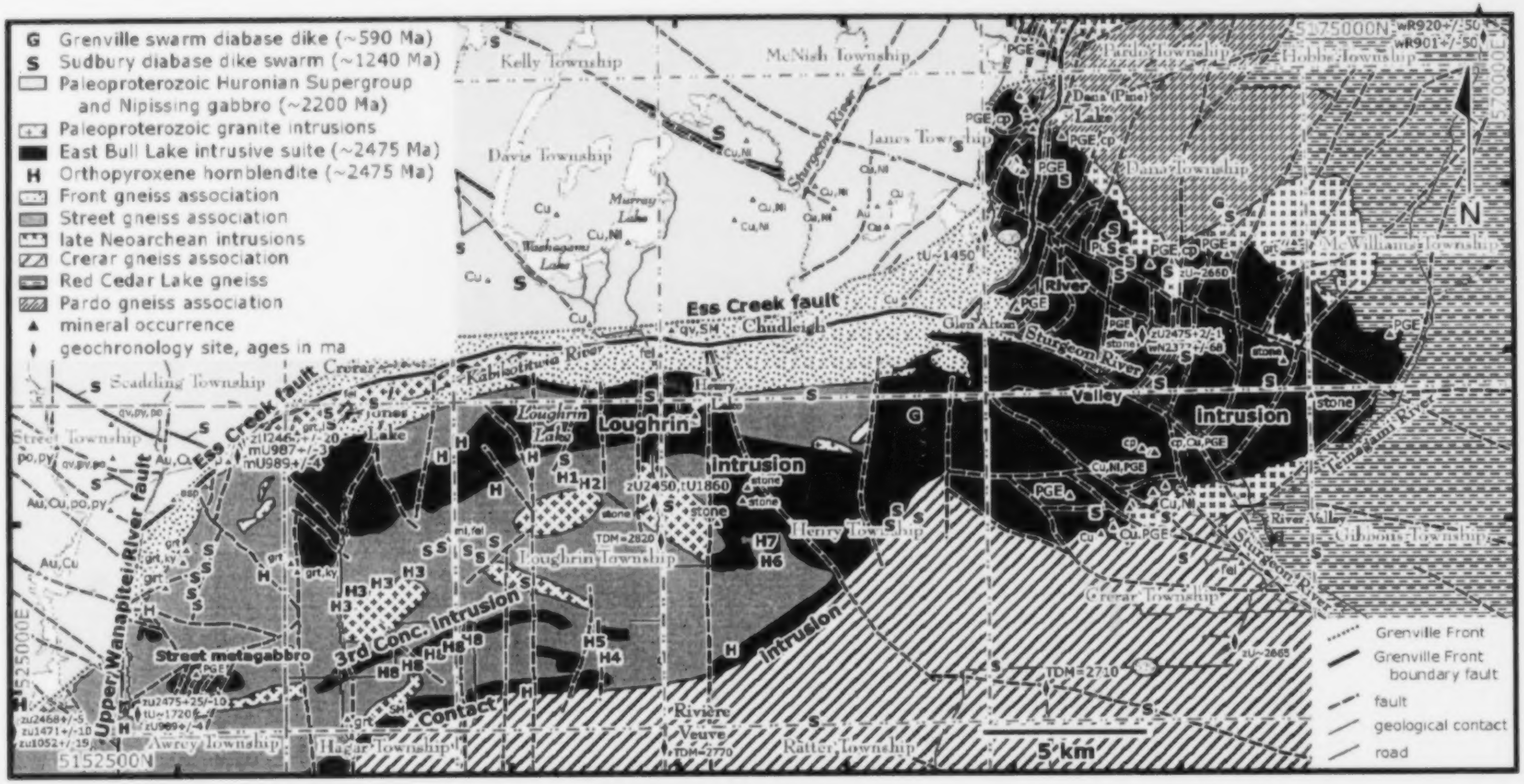

G Grenville swarm diabase dike (~590 Ma)
S Sudbury diabase dike swarm (~1240 Ma)
Paleoproterozoic Huronian Supergroup and Nipissing gabbro (~2200 Ma)
Paleoproterozoic granite intrusions
East Bull Lake intrusive suite (~2475 Ma)
H Orthopyroxene hornblendite (~2475 Ma)
Front gneiss association
Street gneiss association
late Neoarchean intrusions
Crerar gneiss association
Red Cedar Lake gneiss
Pardo gneiss association
mineral occurrence
geochronology site, ages in ma
Grenville Front
Grenville Front boundary fault
fault
geological contact
road
Kelly Township
McNish Township
Davis Township
James Township
Pardo Township
Hobbs Township
Dana Township
McWilliams Township
Scadding Township
Street Township
Loughrin Township
Henry Township
Crerar Township
Gibbons Township
Awrey Township
Hagar Township
Ratter Township
Ess Creek fault
Upper Wanapitei River fault
Sturgeon River
Temagami River
Kablotitwia River
Chudleigh
Glen Afton
Rivière Veuve
Loughrin Intrusion
River Valley Intrusion
3rd Conc. intrusion
Contact intrusion
Street metagabbro
Murray Lake
Washagami Lake
Loughrin Lake
Jones Lake
Dana (Pine) Lake
5175000N
5152500N
525000E
570000E
N
5 km
wR920+/-50
wR901+/-50
zU~2660
zU2475+2/-1
wN2377+/-68
zU2450, tU1860
TDM=2820
TDM=2710
TDM=2770
zU~2665
tU~1450
zI1246+/-20
mU987+/-3
mU989+/-4
zU2475+25/-10
tU~1720
zU2468+/-5
zU1471+/-10
zU1052+/-19

Figure 2. Simplified geological map of the study area showing the approximate distribution of the major gneiss associations present within the Grenville Province (*see* Table 3) and rocks of the East Bull Lake intrusive suite. Abbreviations: asp = arsenopyrite; Au = gold; cp = chalcopyrite; Cu = copper; fel = feldspar; grt = garnet; ky = kyanite; m = monazite; mi = mica; N = neodymium/samarium; Ni = nickel; PGE = platinum group elements; po = pyrrhotite; py = pyrite; qv = quartz veins; R = rubidium/strontium; SM = sulphide minerals; TDM = neodymium/samarium model age; t = titanite; U = uranium/lead; w = whole-rock; z = zircon.

Table 1. Summary of publications related to Ontario Geological Survey (OGS) projects 99-007, 99-019, 01-009 and 02-008 focussing on the River Valley intrusion and East Bull Lake intrusive suite rocks in Crerar, Dana, Henry and Loughrin townships.

Author, Title, Source	Comments
OGS Project Number 99-007	
Easton, R.M. and Hrominchuk, J. 1999. Geology and copper-platinum group element mineral potential of Dana and Crerar townships, River Valley area, Grenville Province; *in* Summary of Field Work and Other Activities, 1999, Ontario Geological Survey, Open File Report 6000, p.30-1 to 30-35.	Summary of 1999 field work, contains preliminary whole-rock geochemical and assay data.
Easton, R.M. 2000. Variation in crustal level and large scale tectonic controls on rare-metal and platinum-group element mineralization in the Southern and Grenville provinces; *in* Summary of Fieldwork and Other Activities 2000, Ontario Geological Survey, Open File Report 6032, p.28-1 to 28-16.	Discusses crustal level of River Valley intrusion emplacement and character of country rocks.
Tettelaar, T. 2000. Petrography and geothermobarometry of variably metamorphosed and deformed leucogabbronorites of the River Valley intrusion, Grenville Province, Ontario; Unpublished B.Sc. thesis, Carleton University, Ottawa, Ontario, 59p.	Presents petrographic and thermobarometric results from the River Valley intrusion based on samples collected from Crerar and Dana townships in 1999.
Easton, R.M. and Hrominchuk, J. 2001a. Precambrian geology of Crerar township, Grenville Province; Ontario Geological Survey, Preliminary Map, P.3432, scale 1:20 000.	Presents results of geological mapping in 1999.
OGS Project Numbers 99-007 and 99-019	
Hrominchuk, J.L. 1999. Geology, stratigraphy and copper-platinum group element mineralization of the River Valley Intrusion, Dana Township; *in* Summary of Field Work and Other Activities, 1999, Ontario Geological Survey, Open File Report 6000, p.31-1 to 31-9.	Summary of 1999 field work.
Easton, R.M. and Hrominchuk, J. 2001b. Precambrian geology of Dana township, Grenville Province; Ontario Geological Survey, Preliminary Map, P.3433, scale 1:20 000.	Presents results of geological mapping in 1999 and 2000.
James, R.S., Easton, R.M., Peck, D.C. and Hrominchuk, J.L. 2000. The East Bull Lake intrusive suite, remnants of a ~2.48 Ga large igneous and PGE-enriched metallogenic province in the Sudbury area of the Canadian Shield; A.J. Naldrett symposium, November 5, 2000, Sudbury, Ontario, extended abstract, web-posted only, 4p.	Extended abstract for oral presentation, Sudbury, November 2000, superseded by James, Easton, Peck and Hrominchuk (2002) paper in Economic Geology.
James, R.S., Easton, R.M., Peck, D.C. and Hrominchuk, J.L. 2002. The East Bull Lake intrusive suite: remnants of a ~2.48 Ga large igneous and metallogenic province in the Sudbury area of the Canadian Shield; Economic Geology, v. 97, p.1577-1606.	Summarizes geology and mineral potential of East Bull Lake intrusive suite, including the River Valley intrusion.
James, R.S., Jobin-Bevans, S., Easton, R.M., Wood, P., Hrominchuk, J.L., Keays, R.R. and Peck, D.C. 2002. Platinum group element mineralization in Paleoproterozoic basic intrusions in central and northeastern Ontario, Canada; *in* Geology, geochemistry, mineralogy and mineral beneficiation of platinum group elements, L.J. Cabri, editor, Canadian Institute of Mining and Metallurgy, Special Publication 54, p.339-365.	Summarizes geology and mineral potential of East Bull Lake and Nipissing intrusive suites, including the River Valley intrusion, with an emphasis on examples of mineralization styles.
Easton, R.M. and Hrominchuk, J. 2002. Whole-rock and mineral chemistry, assay, and petrographic data for the River Valley intrusion, Crerar and Dana townships, Ontario; Ontario Geological Survey, Miscellaneous Release-Data 95.	Data collected from 1999-2000 field seasons, plus data from Street Township area.

Table 1. continued.

Author, Title, Source	Comments
OGS Project Number 99-019	
Hrominchuk, J.L. 2000a. Geology, stratigraphy and copper-nickel-platinum group element mineralization of the River Valley intrusion; *in* Summary of Field Work and Other Activities, 2000, Ontario Geological Survey, Open File Report 6032, p.29-1 to 29-12.	Summary of 2000 field work, contains additional whole-rock geochemical data and stratigraphic column.
Hrominchuk, J.L. 2000b. Geology, stratigraphy, geochemistry, and copper-nickel-platinum group element mineralization in the River Valley; Society of Economic Geologists, Laurentian University Student Chapter, PGM Exploration Short Course, Abstract, 5p.	Extended abstract for oral presentation at short course, Sudbury, October 2000.
Hrominchuk, J.L. and Jobin-Bevans, S. 2000. The River Valley intrusion an early Paleoproterozoic mafic intrusion of the East Bull Lake suite, Sudbury region, Ontario, Canada: a field guide to the general geology, stratigraphy and PGE mineralization; Society of Economic Geologists, Laurentian University Student Chapter, PGM Exploration Short Course, Guidebook, 25p.	Field trip guidebook covering the River Valley intrusion in parts of Dana Township. Trip run in October 2000.
Hrominchuk, J.L., James, R.S. and Easton, R.M. 2001a. Platinum Group Element—Copper—Nickel Mineralization in the River Valley Intrusion, mechanisms and models; Northeastern Ontario Mineral Symposium, Abstracts Volume, p.12.	Abstract for oral presentation, Ontario Prospectors Association, Northeast Symposium, Sudbury, April 2001.
Hrominchuk, J.L., James, R.S. and Easton, R.M. 2001b. Platinum Group Element—Copper—Nickel Mineralization in the River Valley Intrusion, Geological Association of Canada, Abstracts Volume, St. John's, 2001, p.67.	Abstract for oral presentation, Geological Association of Canada-Mineralogical Association of Canada Annual Meeting, St. John's, Newfoundland, May 2001.
Hrominchuk, J.L., Easton, R.M. and James, R.S. 2001c. Geology, stratigraphy, and geochemistry in the River Valley intrusion; Geological Association of Canada, Abstracts Volume, St. John's, 2001, p.67.	Abstract for poster presentation, Geological Association of Canada-Mineralogical Association of Canada Annual Meeting, St. John's, Newfoundland, May 2001.
Hrominchuk, J.L. 2001. Contact style PGE-Cu-Ni mineralization in the East Bull Lake mafic intrusive suite, Sudbury area, Ontario; Society of Economic Geologists, Laurentian University Student Chapter, PGM Exploration Short Course #2, Abstract, 1p.	Abstract for oral presentation at short course, Sudbury, October 2001.
OGS Project Number 01-009	
Easton, R.M. 2001. Geology of Glen Afton (River Valley area) (41I/9); Ontario Geological Survey, Preliminary Map P.3453, scale 1:50 000.	Updated geological compilation map covering most of the River Valley intrusion, incorporating data from Easton and Hrominchuk (2001a, 2001b) and McNish and Janes townships performed since the 1973 River Valley 1:63 360 scale compilation map (Lumbers 1973).
OGS Project Number 99-007 and 02-008	
Easton, R.M. 2003. Geology and mineral potential of Proterozoic mafic intrusions in the northern Grenville Province of Ontario; 49th Institute on Lake Superior Geology, Proceedings, Volume 49, part 1, p.16-17.	Abstract for poster presentation at 2003 Institute on Lake Superior Geology meeting in Iron Mountain, Michigan; poster also presented at Ontario Prospectors Association Symposium in Toronto in December 2002 and the Northeast Symposium in Haileybury in April 2003.
OGS Project Number 02-008	
Easton, R.M. 2002. Geology and mineral potential of Henry and Loughrin townships, Grenville Province; *in* Summary of Field Work and Other Activities 2002, Ontario Geological Survey, Open File Report 6100, p.15-1 to 15-16.	Summary of 2002 field work.

In addition to these mapping projects, a partnership agreement with the Mineral Exploration Research Center at Laurentian University and the Ontario Geological Survey was established in May 1999 (OGS Project Number 99-019). This partnership agreement supported an Ontario Geological Survey–Laurentian University mapping school project that focussed on the stratigraphy, petrography, geochemistry and mineral potential of the River Valley intrusion. The mapping school program is designed to encourage mapping-based research projects within Ontario, both to give students mapping experience and to allow for research beyond the scope of normal Ontario Geological Survey mapping projects. In this instance, field work related to this MSc thesis project was conducted by J.L. Hrominchuk in 1999 and 2000, in conjunction with 1:20 000 scale mapping of Crerar and Dana townships by R.M. Easton in 1999. Dr. R.S. James of Laurentian University and R.M. Easton supervised the thesis project. Preliminary results of the mapping school project are summarized in Hrominchuk (1999, 2000) and James et al. (2002a).

R.M. Easton and E.I. Murphy (Easton and Murphy 2002) mapped Street Township in 1996. This mapping preceded the exploration interest in the study area, but was important in first identifying anomalous platinum group element contents in rocks of the East Bull Lake intrusive suite in the Grenville Province (Easton 1998). The study also developed techniques for mapping the country rock gneisses that were subsequently applied to the remainder of the study area.

Crerar and Dana townships were mapped during a sixteen-week period between June and September 1999 by R.M. Easton and J.L. Hrominchuk; with the results published in 2001 (Easton and Hrominchuk 2001a, 2001b). W. Carter, A. Lundquist and T. Tettelaar provided excellent field assistance to both mappers in 1999. T. Tettelaar also conducted several independent traverses and undertook a BSc thesis project at Carleton University between September 1999 and March 2000 (Tettelaar 2000). This petrographic and thermobarometric thesis study focussed on two sample sites from the River Valley intrusion; one site in Dana Township and one in Crerar Township south of the Sturgeon River.

Easton (2000) addressed the nature of the footwall of the River Valley intrusion and some aspects of the emplacement of the East Bull Lake intrusive suite. Compilation of the Glen Afton map area (Easton 2001) was undertaken in the summer of 2001 with the assistance of E. Murphy.

Henry and Loughrin townships were mapped during an eight-week period between July and August 2002 by R.M. Easton and M. terMeer, and during a subsequent seven-week period between September and October 2002 by R.M. Easton (Easton 2002b; Easton and terMeer in prep.). L. Renaud provided excellent field assistance to both mappers in 2002. In addition, geochronology sampling related to both the 1999 and 2002 mapping programs was conducted by the author and J.W.F. Ketchum of the Jack Satterly Geochronology Laboratory, Royal Ontario Museum in August 2002, with analytical work by S. Kamo of the Jack Satterly Geochronology Laboratory, Royal Ontario Museum.

Geological mapping was conducted using vertical aerial photographs at a scale of 1:20 000, obtained from by the Air Photo Library, Public Information Centre, Ontario Ministry of Natural Resources. Acetate overlays were used to record data that was collected on traverses by the pace and compass method. Geology was not tied to surveyed lines. Traverses were not spaced at regular intervals, but were designed to include as many of the major outcrop areas as possible, particularly in areas of complex geology and along contacts between major rock units.

Information from mapping was plotted on Ontario Basic Mapping (OBM) 1:20 000 base maps supplied by the Ontario Ministry of Natural Resources, which were digitally combined and simplified. Recent information with respect to roads, buildings, powerlines, rock and shoreline features, were added to the resulting base maps.

Reference to specific locations (e.g., photographs, samples) in the text are given in UTM co-ordinates because of the ability to pinpoint locations more precisely than by using latitude and longitude. The map area is located in UTM Zone 17T, and co-ordinates are given using the NAD83 datum. Henry, Loughrin and Dana townships are only partly subdivided into lots and concessions, consequently, reference to lots and concessions with respect to mineral occurrences is not utilized in this report.

TERMINOLOGY

A number of terms used in the discussion of the general geology are outlined below.

Precambrian Time Scale

The Precambrian time scale as subdivided by Easton (1999b) is used in this report. This is an updated version of the time scale used for Geology of Ontario (Ontario Geological Survey 1992a). Precambrian time is divided into two eons; the Archean (older than 2500 Ma), and the Proterozoic (between 2500 and 543 Ma). The Proterozoic is divided into three eras: Paleoproterozoic (2500 to 1600 Ma); Mesoproterozoic (1600 to 900 Ma); and Neoproterozoic (900 to 543 Ma). The Geon time scale of Hofmann (1990) is used to describe intervals of geologic time.

Huronian Supergroup Stratigraphy

Stratigraphic subdivision of the Huronian Supergroup follows the recommendations of the Federal-Provincial Committee on Huronian Stratigraphy (Robertson, Card and Frarey 1969), as modified by Bennett, Dressler and Robertson (1991) and Debicki (1990).

Rock Classification

Terminology for all plutonic rocks in the area follows that of Streckeisen (1976). For metamorphic rocks, mineral prefixes are listed in order of relative abundance, starting with least abundant first. Mineral abbreviations follow Kretz (1983.) The following conventions are used regarding descriptive adjectives. A *gneissic granite* is a meta-igneous rock of granitic composition. A *granitic gneiss*, a *granite gneiss*, or a *gneiss of granitic composition* may be either a meta-igneous or a metasedimentary rock. Similarly, a *tonalitic gneiss* or a *tonalite gneiss* is a gneiss of tonalite modal composition, but may be of either meta-igneous or metasedimentary origin. A *gneissic meta-arkose* is a metasedimentary gneiss of overall granitic composition.

The term metamorphic grade is used in the case where bulk-rock composition or other factors prevent a more detailed assignment of metamorphic conditions. Where metamorphic conditions can be outlined more precisely, the metamorphic facies terminology of Turner (1981) is used.

Foliation, Schistosity, Gneissosity, Cleavage

Foliation is used to describe all types of megascopically recognizable structural surfaces of metamorphic origin (Turner and Weiss 1963). Several distinguishable types of foliation include compositional layering and preferred orientation of mineral grains. Bedding and schistosity are the most common varieties of foliation in the map area. Schistosity is a planar structure in a metamorphic rock due to abundant, preferentially oriented grains, especially micas. Schistosity is accompanied by a fissility in the rock, and is best developed in micaceous rocks. Gneissosity denotes a layering of metamorphic origin, defined by the alternation of layers, streaks, or lenticles of contrasting mineralogy or texture. The streaks or lenticles may be discontinuous. Cleavage denotes a parting in the rock resulting from the parallel growth of micaceous or elongated minerals in fine- to medium-grained rocks.

Layering Thickness Terms

Layering thickness terms used in this report are listed below. These terms apply to bedded, layered and gneissic rocks.

Very thinly layered	<3 cm
Thinly layered	3 to 10 cm
Medium layered	10 to 30 cm
Thickly layered	30 to 100 cm (1 m)
Very thickly layered	1 to 3 m
Extremely thickly layered	>3 m

Migmatite Terminology

A migmatite is a heterogeneous rock composed of two or more components, one generally quartzofeldspathic in composition (leucosome or neosome) and the other more mafic in composition (paleosome or mesosome). Within the study area, such rocks are commonly layered, and in many instances, are formed by partial melting during high-grade regional metamorphism. Descriptive terminology for these rocks follows Mehnert (1969). Other related terms used herein are: metatextite - a rock resulting from moderate degrees of partial melting, in which leucosome is subordinate to mesosome; and diatextite - a rock resulting from high degrees of partial melting, and containing substantial amounts of leucosome.

Geochemical Methods and Terminology

Except where otherwise stated, all chemical analyses that appear in this report were done at the Geoscience Laboratories, Ontario Geoservices Centre, Sudbury. All chondrite-normalized rare earth element diagrams shown in this report use the chondrite normalizing values of Sun and McDonough (1989). Geochemical data collected during this study is listed in Appendix 2 for country rocks, and Appendix 3 for rocks of the East Bull Lake intrusive suite. Analytical methods are described in Vander Voet and Riddle (1993). Sample numbers less than 99RME-1000 and less than 02RME-1000 refer to samples collected by R.M. Easton. Sample numbers greater than 99RME-2000 were collected by J.L. Hrominchuk, and sample numbers greater than 02RME-2000 were collected by M. terMeer. Mineral chemistry data collected as part of this study can be found in Easton and Hrominchuk (2002).

Where geochemical data is available for mafic rocks, rock names based on normative mineralogy following IUGS nomenclature are given in italics for comparative purposes (e.g., melanoamphibolite = *gabbronorite*). This approach is similar to that used by Peck et al. (1995) in studying the East Bull Lake intrusion. With respect to assay data, the term anomalous is used with reference to background levels determined empirically by this study.

Regional Geological Setting

INTRODUCTION

Figures 1 and 2 illustrate the regional geological setting of the study area. It lies adjacent to the boundary between the Paleoproterozoic Southern Province and the Mesoproterozoic Grenville Province, and lies immediately east of the Sudbury Structure. Table 2 provides a summary of the major geological events and the age of the main rock units within the Sudbury area.

The geology of the River Valley intrusion cannot be fully appreciated without an understanding of the regional stratigraphic and structural elements that converge in this part of the Canadian Shield. This background information is reviewed under the following headings: 1) Proterozoic rocks in the Sudbury area, 2) major fault systems, and 3) the Grenville Front.

PROTEROZOIC ROCKS IN THE SUDBURY AREA

Proterozoic rocks in the Sudbury area are assigned to either the Paleoproterozoic Southern Province or the Mesoproterozoic Grenville Province. The Southern Province in Ontario comprises Paleoproterozoic metasedimentary and metavolcanic rocks of the Huronian Supergroup and gabbroic intrusions of the Nipissing gabbro suite. Also included in the Southern Province are the Sudbury Igneous Complex and the Whitewater Group; plutonic and minor volcanic rocks of the Killarney Magmatic Belt; and rocks of the Sudbury diabase dike swarm (*see* Figure 1; Bennett, Dressler and Robertson 1991).

The Huronian Supergroup was deposited unconformably on Archean plutonic and supracrustal rocks of the Superior Province. The lowest unit, the Elliot Lake Group, consists of both metavolcanic and metasedimentary rocks. In the Sudbury area, the metavolcanic units include tholeiitic basalts of the Elsie Mountain Formation, evolved tholeiitic basalts, dacites, and metasedimentary rocks of the Stobie Formation, and dacites and rhyolites of the ~2450 Ma Copper Cliff Formation. The latter are likely coeval with the Murray and Creighton granites (Bennett, Dressler and Robertson 1991). The metavolcanic units interfinger with, and are overlain by the Matinenda Formation in the west and the McKim Formation in the east. Geochemical data reported by Innes (1972, 1977) and Easton (1998) indicate a tholeiitic affinity for the Stobie Formation, whereas felsic metavolcanic rocks of the Copper Cliff Formation and the Murray and Creighton granites show calc-alkalic signatures.

At the base of the Huronian Supergroup in the Elliot Lake, Agnew Lake and Sudbury areas are several layered gabbro to anorthosite intrusions referred to as the East Bull Lake intrusive suite (Peck, James and Chubb 1993; James et al. 2002a, 2002b). These bodies have been dated at 2491 to 2475 Ma (Krogh, Davis and Corfu 1984), and appear to be slightly older than the rocks of the Elliot Lake Group. The geology of the East Bull Lake intrusive suite is described in detail in the section on "East Bull Lake Intrusive Suite Rocks, Overview".

Each of the three groups overlying the Elliot Lake Group consists of sedimentary cycles of conglomerate, mudstone, siltstone or carbonate, capped by cross-bedded sandstone (Bennett, Dressler and Robertson 1991). Conglomerate units (e.g., Ramsey Lake, Bruce and Gowganda formations) in each of the cycles have been interpreted as being glaciogenic in origin, likely deposited in a marine environment adjacent to an ice shelf. The siltstone and sandstone units are interpreted to represent deposition during warmer intraglacial or post-glacial periods in either fluvial or marine environments (Junnila and Young 1995; Fralick and Miall 1989). Huronian deposition was complete by 2220 Ma, the age of the Nipissing gabbro suite (Corfu and Andrews 1986; Noble and Lightfoot 1992).

Table 2. Timing of major geological events and summary of age constraints on the main rock units present in the study area.

Event and/or Map Unit	Age Constraint (in Ma)	Comment and/or Source
Grenville dike swarm	586±4	Kamo, Krogh and Kumarapeli (1995)
Pegmatite vein emplacement	989±2	Corfu and Easton (2000)
Age of peak metamorphism in the hangingwall of the Grenville Front tectonc zone	1000 to 990	Corfu and Easton (2000), this study
Age of peak Grenvillian metamorphism in the Central Gneiss Belt	1040 to 1030	Carr et al. (2000)
Sudbury dike swarm	1238±4	emplaced in or along northwest-trending faults in the Southern Province. Deformed and metamorphosed within the Grenville Province. Krogh et al. (1987)
Killarney magmatic belt second-stage magmatism, coincident with magmatism in the Eastern Granite Rhyolite Province and in the Central Gneiss Belt	1471±3	van Breemen and Davidson (1988)
Regional albitization metasomatic event	1701±4	U/Pb monazite, Schandl, Gorton and Davis (1994); fluid focussed along northwest-trending faults
Killarney magmatic belt volcanism and high-level plutonism	1740, 1747±3, 1749±12	van Breemen and Davidson (1988); Sullivan and Davidson (1993); Davidson and van Breemen (1994)
Northwest-trending regional faults	Pre-1700, post-1850	Faults cut Sudbury Structure
Penokean orogeny (folding and metamorphism of Huronian Supergroup rocks)	~1835	Peak metamorphism. Holm et al. (2001)
Impact event and formation of Sudbury Breccia	1850±1	Krogh, Davis and Corfu (1984)
Thrust faulting	post-F_2 pre-regional faulting	Sudbury breccia localized along these faults, suggesting they are pre-Sudbury Structure
F_2 folding	post-2200, pre-1700, pre-1850?	Pre-regional faulting, Nipissing sills folded, relationship to Sudbury Structure uncertain
F_1 folding	pre-2200	Nipissing sills in Street Township appear unaffected by this folding
Emplacement of Nipissing gabbro sills	2219±4 to 2210±4	Corfu and Andrews (1986); Noble and Lightfoot (1992)
Huronian sedimentation	>2220 but <2460	
Huronian felsic volcanism and related plutonic rocks	~2477 to 2375 (2450±25, 2460±20, 2477±9, 2415±5, 2376±2)	Krogh, Davis and Corfu (1984); Corfu and Easton (2000); Krogh, Kamo and Bohor (1996); Smith (2002)
Emplacement of East Bull Lake intrusive suite rocks	2475±2 see also Table 8	Heaman (geochronologist, University of Alberta, personal communication, 1999)
Emplacement of orthopyroxene hornblendite bodies	2468±5	Corfu and Easton (2000)
Emplacement of alkali feldspar granite bodies in Crerar and Dana townships	~2660	Bodies intrude Crerar and Pardo gneiss, this study
High-grade Archean metamorphism and migmatization	2647±4	Krogh, Davis and Corfu (1984); Wodicka and Card (1995)
Emplacement of megacrystic granodiorite bodies in Crerar gneiss association	~2665	this study
Emplacement ages of Archean units in the Sudbury area	2711±7 to 2642±1 see also Table 4	Krogh, Davis and Corfu (1984); Wodicka and Card (1995); Chen, Krogh and Lumbers (1995); Meldrum et al. (1997)

The Huronian Supergroup has been interpreted to represent a Wilson cycle, starting from a rifting phase represented by the Elliot Lake, Hough Lake and Quirke Lake groups; followed by a passive margin sequence (Cobalt Group); and concluded by a continent-arc collision between the Superior-Southern provinces and the Wisconsin Magmatic Arc Terrane (e.g., Young 1983; Hoffman 1989; Bennett, Dressler and Robertson 1991). This collisional event at 1870 to 1835 Ma, termed the Penokean Orogeny, is believed to be responsible for most of the metamorphism and deformation present within the Huronian Supergroup. The scale and intensity of the Penokean Orogeny remain the subject of debate (Davidson, van Breemen and Sullivan 1992; Card 1992), in part because the Penokean Orogeny has no associated plutonism in Ontario. In contrast, Riller et al. (1999) attributed deformation and peak metamorphism of the Huronian Supergroup to the 2470 to 2220 million-year-old Blezardian Orogeny, with subsequent transpressional deformation during the Penokean Orogeny. These divergent views reflect the lack of constraints on the age of Huronian metamorphism and deformation.

The Sudbury Igneous Complex was emplaced at 1850 Ma (Krogh, Davis and Corfu 1984) and consists of a lower, ore-bearing sublayer, a main mass of norite, and an upper granophyre (e.g., Dressler, Gupta and Muir 1991). Associated with the Sudbury Igneous Complex are brecciated rocks, termed the Sudbury breccias (e.g., Dressler, Gupta and Muir 1991), consisting of randomly oriented blocks of country rock in a fine-grained, pseudotachylite matrix. The breccias occur up to 200 km from Sudbury, but are most abundant near Sudbury. The Sudbury Igneous Complex and related rocks has been variously interpreted as originating from meteorite impact, impact-induced plutonism and volcanism, and volcanism (*see* reviews in Pye, Naldrett and Giblin 1984). The southern part of the Sudbury Igneous Complex was weakly metamorphosed by an event that also retrograded metamorphic rocks of the Huronian Supergroup. Regional sodium and potassium metasomatism and silicification has intensely altered rocks locally within the Huronian Supergroup, especially along faults, at ~1700 Ma (Meyer et al. 1990; Gates 1991; Schandl, Gorton and Davis 1994; Easton et al. 1996; Fedo et al. 1997). Significant magmatism occurred at 1750 to 1730 Ma and again at 1500 to 1450 Ma in the Killarney Magmatic Belt (van Breemen and Davidson 1988; Davidson and van Breemen 1994; Krogh 1994).

The last major magmatic activity in the Southern Province occurred at 1240 Ma with the emplacement of the northwest-trending Sudbury diabase dike swarm (Krogh et al. 1987). This event is noteworthy, as rocks of this dike swarm can be traced across the Grenville Front into the Grenville Front tectonic zone, providing an important marker horizon (e.g., Bethune 1997).

Significant changes in thickness within the Huronian Supergroup occur east and west of a line roughly coincident with the trace of the north-trending Upper Wanapitei River fault (*see* Figure 1). Debicki (1990) estimated the thickness of the Huronian Supergroup in the Sudbury-Coniston area to be roughly 10 350 m, 85% of which consists of the lower 3 groups. In contrast, east and northeast of Wanapitei Lake, the thickness of the Huronian Supergroup is roughly 6250 m, 75% of which consists of the Cobalt Group. The Elliot Lake, Hough Lake and Quirke Lake groups are all considerably thinner east of Wanapitei Lake, and the McKim and Ramsey Lake formations are apparently absent (Easton and Murphy 2002).

MAJOR FAULT SYSTEMS

Upper Wanapitei River Fault

The Upper Wanapitei River fault (*see* Figure 1) has had a protracted deformation history, exhibiting at least 7 to 8 km of left-lateral movement between 2170 and 1850 Ma (Buchan and Ernst 1994), and at least 3 km of left-lateral movement post-1040 Ma (Easton and Murphy 2002). According to Easton (2000), the north-trending Upper Wanapitei River fault apparently divides the Archean rocks in the Elliot Lake to North Bay area into two domains, with the boundary between these domains passing through Street Township. The eastern domain, which includes the River Valley–Hagar area consists of supracrustal and metaplutonic rocks, with deeper levels in the crust being exposed, likely due to Grenville orogenesis, to the south. In contrast, the western domain is pluton-dominated, with deeper levels of the crust being exposed to the east. The amount of vertical movement across the fault is unknown. Significant vertical movement would be necessary to juxtapose granulites of the Levack gneiss complex against higher-crustal-level rocks to the east, however, if the Upper Wanapitei River fault reactivated an older listric fault system, then considerably less relative uplift across the fault may be present.

Murray Fault System

Significant changes in stratigraphic thickness within the Huronian Supergroup occur across some regional faults, in particular, the Murray fault system (e.g., Bennett, Dressler and Robertson 1991, and references therein). North of the Murray fault, the McKim Formation is tens of metres thick, whereas south of the fault, it probably excedes 1000 m. The thickness and facies variations across the Murray fault system suggest that the faults represent south-side-down, syn-sedimentary, growth faults that were reactivated during compression related to the Penokean Orogeny (e.g., Zolnai, Price and Helmstaedt 1984).

In addition to stratigraphic thickness variations, the Murray fault system also marks profound changes in structural style, metamorphic grade and magmatic associations (Card et al. 1972). Deformation is more complicated and of greater intensity south of the fault. Likewise, metamorphic grade is higher immediately south of the fault (amphibolite facies transitional southward to greenschist facies) than to the north (greenschist to subgreenschist facies). South of the fault, there are several 1750 Ma and younger granitoid complexes (e.g., Cutler batholith) (Davidson and van Breemen 1994), whereas, north of the fault, there are no such intrusions.

Northeast of Coniston, the Grenville Front boundary fault and the Murray fault system are thought to merge into the Wanapitei fault (Davidson 1997), which can be traced into Street Township. This fault is then offset to the north by the Upper Wanapitei River fault, and continues eastward as the Ess Creek and Grenville Front boundary faults along the trend of the Kabikotitwia and Sturgeon rivers (Easton and Murphy 2002). Therefore, in the study area, Huronian strata located west and northwest of the Wanapitei and Ess Creek faults occur north of the Murray fault system, whereas any Huronian rocks preserved within the Grenville Province would have originally been deposited south of the Murray fault system.

THE GRENVILLE FRONT

The Grenville Front tectonic zone is a region up to 30 km across lying between the Grenville Front and the Central Gneiss Belt of the Grenville Province (*see* Figure 1). Easton (1992) divided the Grenville Front tectonic zone in Ontario into 3 lithologic segments. The western segment between Killarney and Wahnapitae comprises rocks equivalent in age, geophysical signature, and rock type to the adjacent Killarney Magmatic Belt. The central segment stretches from Wahnapitae to River Valley, and contains mafic intrusive rocks of both the East Bull Lake and the Nipissing intrusive suites, as well as several types of migmatitic gneisses, likely of Neoarchean age (Easton 2000). The eastern segment, between River Valley and the Ottawa River, includes rocks mainly derived from the adjacent Superior Province. The study area lies mainly in the central segment, although the eastern part of the study area straddles the boundary between the central and eastern segments.

The Grenville Front is a zone of southeast-dipping faults and mylonites and has generally been placed at the southeast limit of recognizable Southern Province rocks (e.g., Lumbers 1975; Davidson 1997). Locally there are complications that have led to many debates concerning the identity of the Grenville Front and its distinction from other faults that intersect, merge with or are parallel to the Front (see discussion in Davidson 1997). In central Street Township the Grenville Front (which is coincident with the Wanapitei fault) has been displaced to the north by the younger, north-trending, Upper Wanapitei River fault by at least 850 m of sinistral and west-side-up movement (Easton and Murphy 2002). This displacement likely occurred after ~ 590 Ma, as a Grenville swarm diabase dike in northern Henry and Loughrin townships is also displaced by north-trending faults.

Between Kukagami Road in Street Township eastward to Glen Afton in Dana Township, the Grenville Front trends easterly. In this part of the study area, Lumbers (1973) placed the Grenville Front (or more precisely, the Grenville Front boundary fault) along a zone of cataclasis that separated migmatitic gneisses to the south from non-migmatitic, amphibolite facies rocks to the north. Work by Easton et al. (1996) and Easton and Murphy (2000, 2002) in the same area indicated that a 1 to 2 kilometre wide belt of rocks occurred between the Ess Creek fault (Thomson and Card 1963) and the Grenville Front boundary fault of Lumbers (1973). This belt consisted of rocks of the Huronian Supergroup and the Nipissing intrusive suite that had been subjected to amphibolite facies metamorphism during the Grenville orogeny (Corfu and Easton 2000). Consequently, Easton (2001) and Easton and Murphy (2002, 2002), placed the Grenville Front in this part of the study area along the trace of the Ess Creek fault. This placement of the Grenville Front is the one utilized in this report.

Near Glen Afton along the Sturgeon River, the Grenville Front changes direction from an easterly trend to a north-northeasterly trend. The trace of the Grenville Front in this area lies near the boundary between Janes and Dana townships. Here, Lumbers (1973) placed the Grenville Front boundary fault east of Highway 805, running almost due north from Glen Afton through Dana Lake (Easton and Hrominchuk 2001b). Davidson (1986) identified the presence of mylonites west of the Grenville Front boundary fault in Dana Township. He suggested that the Grenville Front was located west of the Grenville Front boundary fault, perhaps at the boundary between the River Valley intrusion and structurally underlying Mississagi Formation rocks (Davidson 1986, p.12). Placement of the Grenville Front west of the Grenville Front boundary fault, as suggested by Davidson (1986) is also consistent with metamorphic mineral assemblage data in adjacent Janes Township, presented by Dressler (1979, p.66). These data indicate that the region west of the Grenville Front boundary fault contains higher grade mineral assemblages than is typical of the Southern Province. Easton and Hrominchuk (1999, 2001b) placed the Grenville Front in roughly the same location suggested by Davidson (1986). Grenvillian deformation in the area between the Grenville Front and the Grenville Front boundary fault is localized along numerous ultramylonite zones varying from several metres to several hundred metres in width, with intervening zones containing relatively undeformed rocks, which appear to retain remnants of original stratigraphy.

COUNTRY ROCKS

Archean and Proterozoic

INTRODUCTION

Culshaw et al. (1988) introduced the concept of "gneiss associations" for mapping highly deformed and metamorphosed rocks of the Central Gneiss Belt of the Grenville Province. A "gneiss association" is an informal stratigraphic term that is primarily lithological, but which also may contain information with respect to plutonic history, metamorphism or mafic diking. If it were decided to formally name a "gneiss association" as a lithodemic unit under the North American Stratigraphic Code (NACSN 1983), in most cases, they would correspond to a suite or a complex.

Easton and Hrominchuk (1999) applied the concept of "gneiss association" to the nomenclature of country rocks of the River Valley intrusion in Crerar and Dana townships. Easton (2002b) further expanded the concept to include rocks in Henry and Loughrin townships, and by inference, Street Township. Country rocks to the East Bull Lake intrusive suite rocks in the study area can be grouped into 4 gneiss associations and one previously defined lithodemic unit; the characteristics of each are summarized in Table 3. From northwest to east, these are the Front, Street, Crerar and Pardo gneiss associations and the Red Cedar Lake gneiss (*see* Figures 1, 2). The Crerar and Pardo gneiss associations and the Red Cedar Lake gneiss likely consist entirely of Neoarchean rocks. The Street gneiss association likely consists mainly of Archean rocks that have been intruded by Proterozoic mafic and felsic intrusive rocks. The Front gneiss association may consist almost entirely of Proterozoic rocks.

Table 3. Comparison of country rock units present within the study area. Rock types listed from top to bottom in order of abundance, with most abundant first. Unit numbers in brackets under the Street gneiss association refer to map units in Street Township (Easton and Murphy 2000, 2002). The Red Cedar Lake gneiss is not included in this table because it is most likely simply a deformed equivalent of the Pardo gneiss association.

Front gneiss association (Proterozoic and minor Archean?)	Pardo gneiss association (Archean)	Street gneiss association (Archean with Proterozoic intrusions)	Crerar gneiss association (Archean)
• granite gneiss, migmatitic (<10% granitic leucosome).	• fine-grained biotite quartzofeldspathic gneiss (metagreywacke) cut by granodioritic to tonalitic leucosome veins which constitute from 5% to 25% of the rock.	• migmatitic, quartzofeldspathic gneiss (unit 23, 22) are the main rock unit, may contain 5-25% garnet distributed throughout the rock in both melanosome and leucosome. Includes diatextite and metatextite	• tonalite and granodiorite gneiss, minor granite gneiss of unknown age.
• straight gneiss, consisting of rocks of mafic and felsic composition, commonly garnet-bearing (5-15%).	• medium-grained, granodioritic to monzogranitic gneiss, possibly representing plutonic rocks that intruded the metasedimentary migmatite.	• migmatitic mafic gneisses common (unit 4, 21) forming major map units, layers and pods.	• megacrystic granodiorite intrusions and dikes.
• mafic and diorite orthogneiss, amphibolite and felsite, locally fragmental, possibly derived from Huronian Sgp. volcanic rocks.		• in northwest Loughrin Township, garnet± aluminosilicate-bearing metasedimentary gneiss (unit 2, 3, 12?) is present.	
• large granite pegmatite veins common and intrude a variety of rock units, most commonly mafic gneisses.	• large granite pegmatite veins common and intrude a variety of rock units.	• large granite pegmatite veins common and intrude a variety of rock units.	• granite pegmatite veins not common, few are outcrop size.
• older mafic dikes not common.	• some Matachewan swarm diabase dikes, weakly metamorphosed.	• older mafic dikes not common.	• 2 or 3 types of mafic dikes, typically boudinaged and folded with gneissosity.
• Sudbury diabase dikes present locally, weakly metamorphosed.	• Sudbury diabase dikes present locally, weakly metamorphosed.	• Sudbury diabase dikes common, weakly metamorphosed.	• Sudbury diabase dikes present locally, strongly metamorphosed.
	• younger granite intrusions generally not common.	• younger granite intrusions common.	• younger granite intrusions generally not common.

PARDO GNEISS ASSOCIATION

The Pardo gneiss lies directly north of the River Valley intrusion in Dana Township (*see* Figure 2). It consists of two main components:

1. fine-grained biotite quartzofeldspathic gneiss (metagreywacke) cut by granodioritic to tonalitic leucosome veins which constitute from 5% to 25% of the rock (Photo 2) and
2. medium-grained, granodioritic to monzogranitic gneiss, possibly representing plutonic rocks that intruded the metasedimentary migmatite.

Distribution of these two components shows considerable variation north of the Sturgeon River in Dana Township. Individual plutons are difficult to outline, and it is possible that the plutonic component was emplaced as a series of sheets into the metasedimentary gneiss, leaving screens of varied size of the metasedimentary country rock. Non-migmatized metawacke and granodiorite occur directly north of the Grenville Front boundary fault in Pardo Township (Lumbers 1973), and likely represent equivalents of the Pardo gneiss preserved at higher structural levels.

Gneissosity and folds in the Pardo gneiss are cut by both the Matachewan and Sudbury dike swarms, the former indicating that the main migmatitic (and folding?) event affecting the Pardo gneiss occurred prior to 2445 Ma, and was likely Neoarchean in age. Effects of Grenville deformation and metamorphism are not apparent in the field, however, thin section examination of both the Pardo gneiss and cross-cutting Sudbury dikes indicate that the area underlain by the Pardo gneiss has been affected by high-grade metamorphism after 1240 Ma.

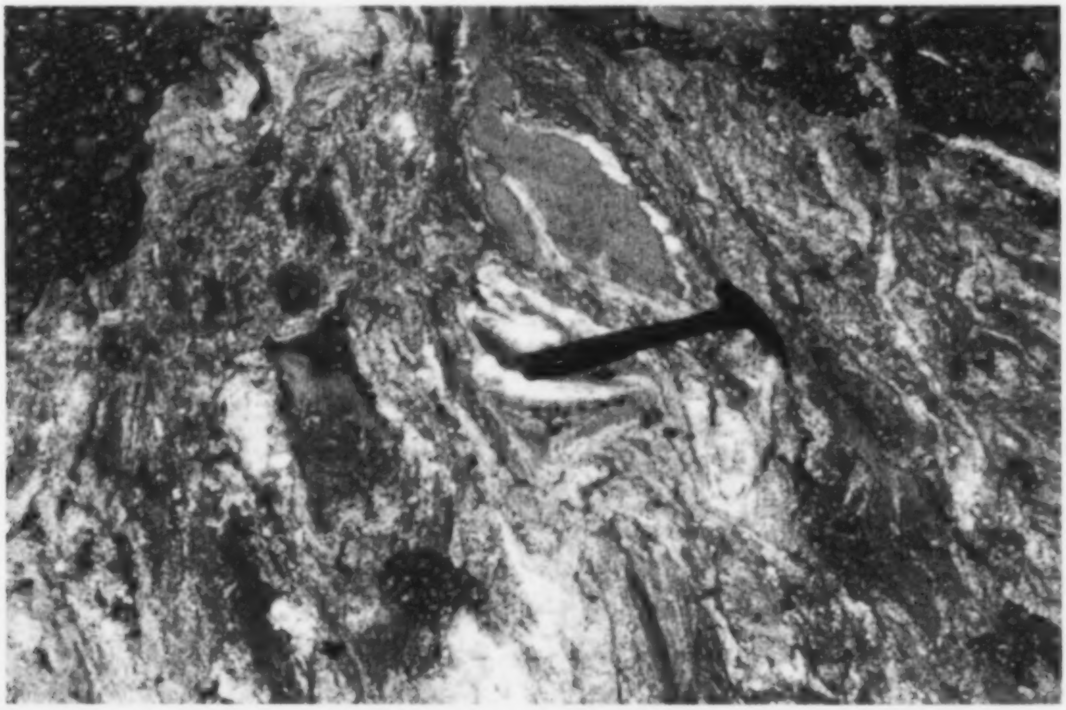


Photo 2. Typical migmatitic paragneiss of Pardo gneiss association, Dana Township. Hammer handle is 30 cm long. Station 99RME-0025. UTM 560016E 5174079N.

The Pardo gneiss is cut by pink- to white-pink-weathering, fine- to medium-grained, gneissic to foliated, granitoid rocks. Lumbers (1973) classified these granitoid rocks as monzonite to quartz syenite, however, geochemistry suggests these rocks are more appropriately termed alkali feldspar granite using the normative classification of Streckeisen (1976). The alkali feldspar granites occur at the contact with the River Valley intrusion in parts of Dana and Crerar townships, and are peraluminous, with low total REE (less than 50 ppm), positive Eu anomalies (Eu/Eu* 7.9), and are corundum-normative, suggesting an S-type affinity (Figure 3a). Breaks and Moore (1992) reported similar REE patterns from their Type 2 phase of the Neoarchean, peraluminous, S-type, Ghost Lake batholith in northwest Ontario (Figure 3a), and suggested that the unusual chemistry of these rocks resulted from feldspar accumulation. Preliminary U/Pb zircon geochronology from an alkali feldspar granite in central Dana Township that is cut by the River Valley intrusion has yielded an age of between 2640 and 2660 Ma (S. Kamo, Geochronologist, Jack Satterly Geochronology Laboratory, Royal Ontario Museum, unpublished data, 2003). The younger part of this age range is similar to the age of the Cartier granite north of Sudbury (Meldrum et al. 1997) and is consistent with suggestions that Archean regional metamorphism in the study area occurred between 2660 and 2640 Ma (e.g., Steiger and Wasserberg 1969; Easton 2000).

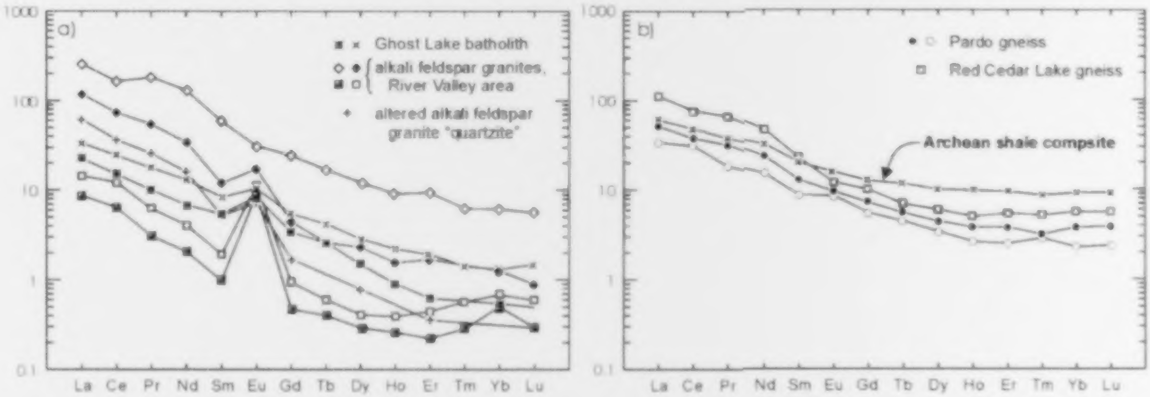


Figure 3. a) Chondrite-normalized rare-earth element plots for alkali feldspar granites cutting the Crerar and Pardo gneiss associations. Representative samples from Type 2 granites of the Ghost Lake batholith (Breaks and Moore 1992) are shown for comparison. **b)** Chondrite-normalized rare-earth element plots for rocks of the Pardo and Red Cedar Lake gneiss associations. Average Archean shale composite of Taylor and McClennan (1985) is shown for reference.

RED CEDAR LAKE GNEISS

The Red Cedar Lake gneiss (Lumbers 1978; *see also* Easton 1992) crops out within the Grenville Front tectonic zone between River Valley and the Ottawa River (*see* Figure 2). In the River Valley area, it consists of granular, granodioritic gneiss (Photo 3) that locally contains abundant fine-grained inclusions of quartzofeldspathic to amphibolitic composition. Easton and Hrominchuk (1999) suggested that the Red Cedar Lake gneiss represented a more flattened and cataclastic equivalent of the Pardo gneiss, perhaps due to an increase in the penetrative character of Grenvillian deformation. The geochemistry of the Red Cedar Lake gneiss is consistent with this suggested linkage to the Pardo gneiss (Figure 3b).

Photo 3. Typical Red Cedar Lake gneiss, near River Valley, Ontario. Hammer handle is 30 cm long. Station 88RME-0555. UTM 563120E 5158590N.

CRERAR GNEISS ASSOCIATION

The Crerar gneiss association (gneiss association III of Easton and Hrominchuk (1999)), underlies most of southern Crerar Township (*see* Figure 2), and is dominated by migmatitic, hornblende tonalitic to granodioritic gneisses (Photo 4). In general these gneisses are flattened, with leucosomes subparallel to gneissosity; locally, these rocks can be termed straight or transposed gneisses. The migmatitic hornblende gneiss unit locally contains 10 to 200 m wide zones of migmatitic amphibolite and calc-silicate layers. All are locally cut by a fine-grained to medium-grained, migmatitic, monzogranite gneiss, which forms sheet-like, semi-concordant bodies. Within the cores of regional folds, the gneiss is less flattened, and consists mainly of a potassium feldspar megacrystic granodiorite (Photo 5). In better exposed areas on the limbs of regional folds, the megacrystic rock becomes progressively deformed to form the flecky-textured, flattened, hornblende granodiorite gneiss typical of this unit. Geochemical data suggests the presence of at least two suites of granodioritic to tonalitic rocks within this gneiss association, consistent with the observations of Chen, Krogh and Lumbers (1995) on equivalent rocks near Hagar (Table 4).

A sample of Crerar gneiss analyzed by Dickin (1998) gave a Nd/Sm model age of 2.73 Ga, and a ^{207}Pb/^{204}Pb ratio of 14.90. The latter was interpreted by Dickin (1998) as indicating that the gneiss was subjected to strong uranium depletion during Archean metamorphism and thus represented a sample of deep-crustal Superior Province basement. Rocks of the Crerar gneiss association are also cut by metamorphosed Sudbury swarm dikes, but to date, no Matachewan swarm dikes have been observed cutting the Crerar gneiss association. The absence of Matachewan swarm dikes may reflect the fact that the Crerar gneiss association represents a deeper crustal level compared to the Pardo gneiss association (Figure 4).

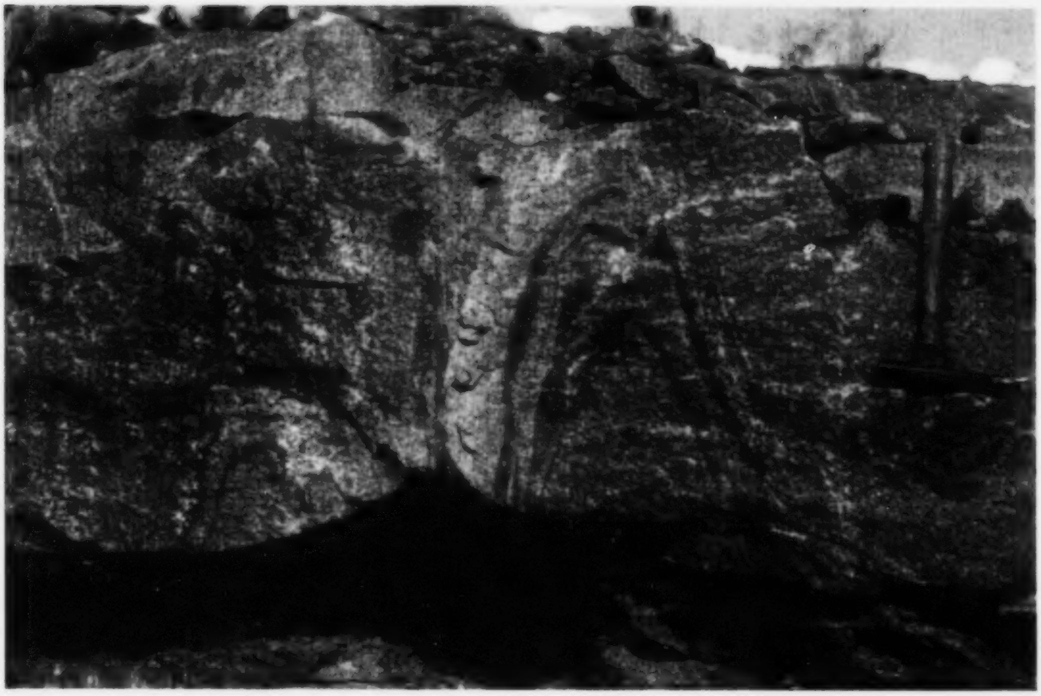


Photo 4. Crerar gneiss association, showing tight fold, near Riviere Veuve, on Highway 535. Hammer handle is 30 cm long. Station 02RME-0004. UTM 544591E 5153508N.

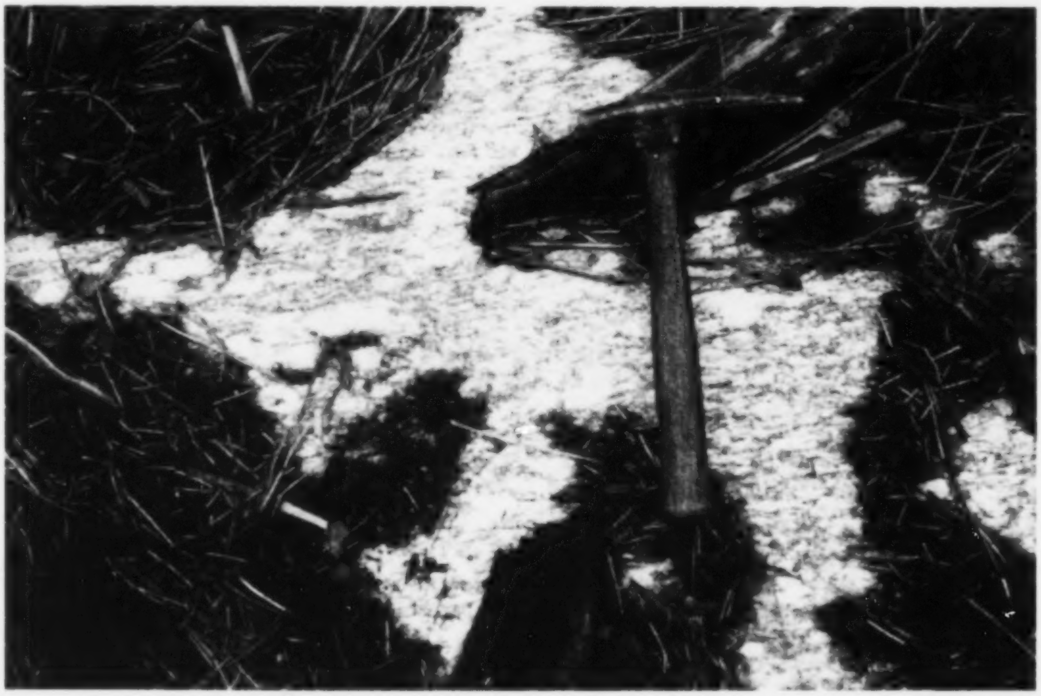


Photo 5. Flattened feldspar megacrystic granodiorite of the Crerar gneiss association, Crerar Township. Station 99RME-0320. UTM 558818E 5159326N.

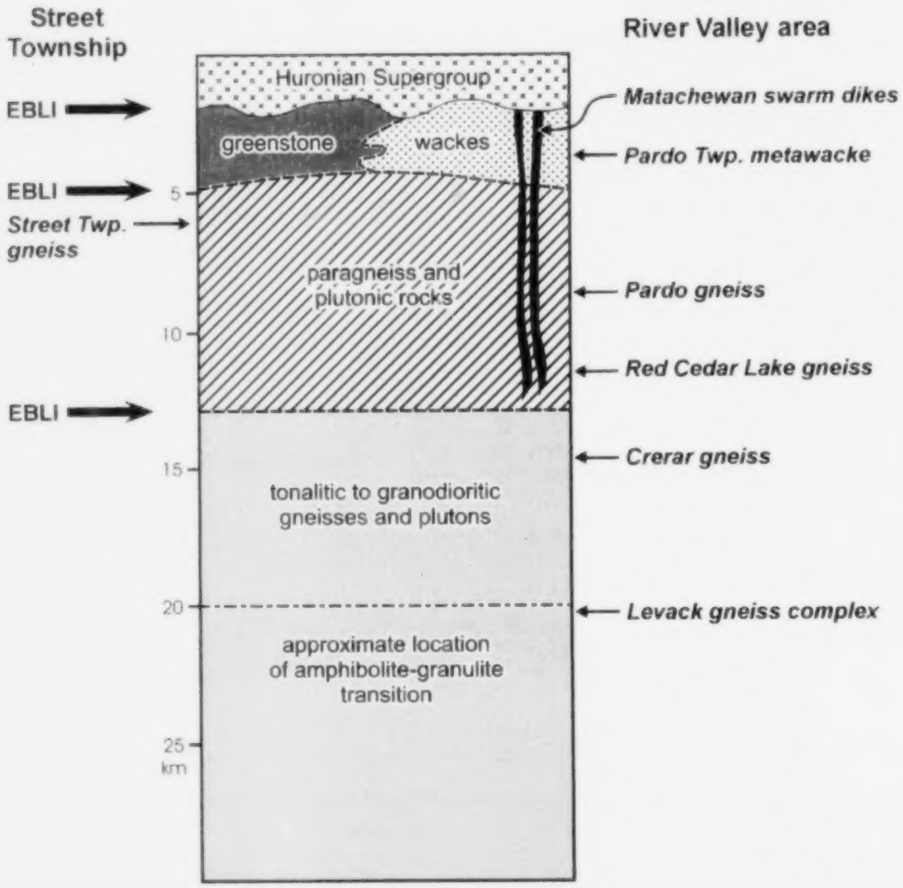

Street Township
River Valley area
Huronian Supergroup
EBLI
Matachewan swarm dikes
greenstone
wackes
Pardo Twp. metawacke
EBLI
5
Street Twp. gneiss
paragneiss and plutonic rocks
Pardo gneiss
10
Red Cedar Lake gneiss
EBLI
15
Crerar gneiss
tonalitic to granodioritic gneisses and plutons
20
Levack gneiss complex
approximate location of amphibolite-granulite transition
25
km

Figure 4. Cartoon illustrating exposed crustal section in the River Valley area. Possible emplacement levels for rocks of the East Bull Lake intrusive suite (EBLI) are illustrated (see text for discussion). Current data from the River Valley area suggests emplacement of the River Valley intrusion into the Pardo gneiss.

The southernmost belt of East Bull Lake intrusive suite rocks in Henry and Loughrin townships (*see* Figure 2) appears to mark the boundary between the Street and Crerar gneiss associations. It is not clear if this contact is tectonic, or whether it represents a lithologic break exploited by the mafic intrusive rocks during their emplacement.

Preliminary U/Pb zircon geochronology from a megacrystic granodiorite collected in central Crerar Township along Highway 539 has yielded an age of 2663±2 Ma (S. Kamo, Geochronologist, Jack Satterly Geochronology Laboratory, Royal Ontario Museum, unpublished data, 2003). This age is slightly younger than the age of either the Tilden trondhjemite (2669±4 Ma, Chen, Krogh and Lumbers 1995) or the Warren trondhjemite (2678-2683 Ma, Chen, Krogh and Lumbers 1995) located just south of the study area. This is consistent with field relationships indicating that the megacrystic granodiorite bodies in the Crerar gneiss association are one of the youngest magmatic components of this gneiss unit. This age also places an upper age limit on Archean regional metamorphism in the study area. Megacrystic granodiorite bodies of ~1450 million-years in age are common further south in the Central Gneiss Belt (e.g., in the Britt and Shawanaga domains). This age eliminates the possibility that the megacrystic granodiorite bodies in the Crerar gneiss association belong to this younger intrusive suite, even though they look superficially similar in the field.

STREET GNEISS ASSOCIATION

The Street gneiss association (Easton 2002b) crops out throughout most of Street and Loughrin townships and in west-central Henry Township (*see* Figure 2) (Photos 6 and 7). It consists of a variety of rock types previously described by the author from Street Township (Easton and Murphy 2002), as summarized in Table 3. Rocks of the Street gneiss association in Henry and Loughrin townships generally contain more leucosome and have less discrete contacts (i.e., are diatextites rather than metatextites), especially the mafic gneisses (Photo 8), than do the equivalent rock units in Street Township. Garnet is also less ubiquitous in the Street gneiss association in Henry and Loughrin townships than it is in Street Township.

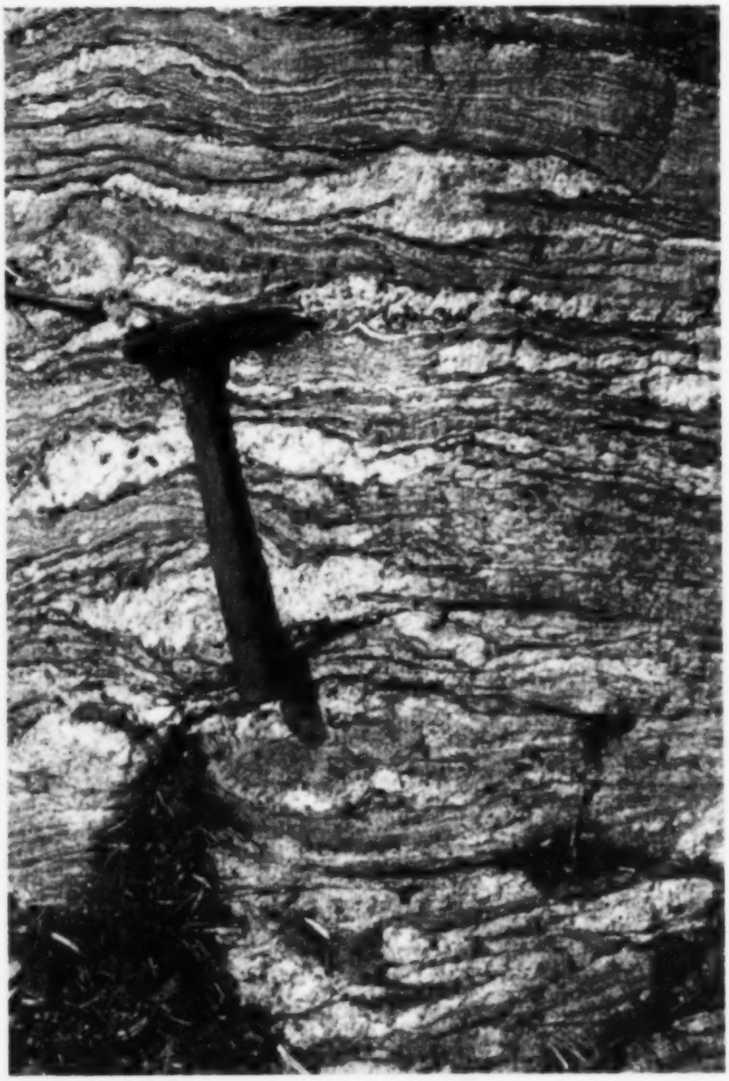


Photo 6. Typical migmatitic quartzofeldspathic, garnet-rich, gneiss of the Street gneiss association. Hammer handle is 30 cm long. Station 02RME-0126. UTM 541240E 5156830N.

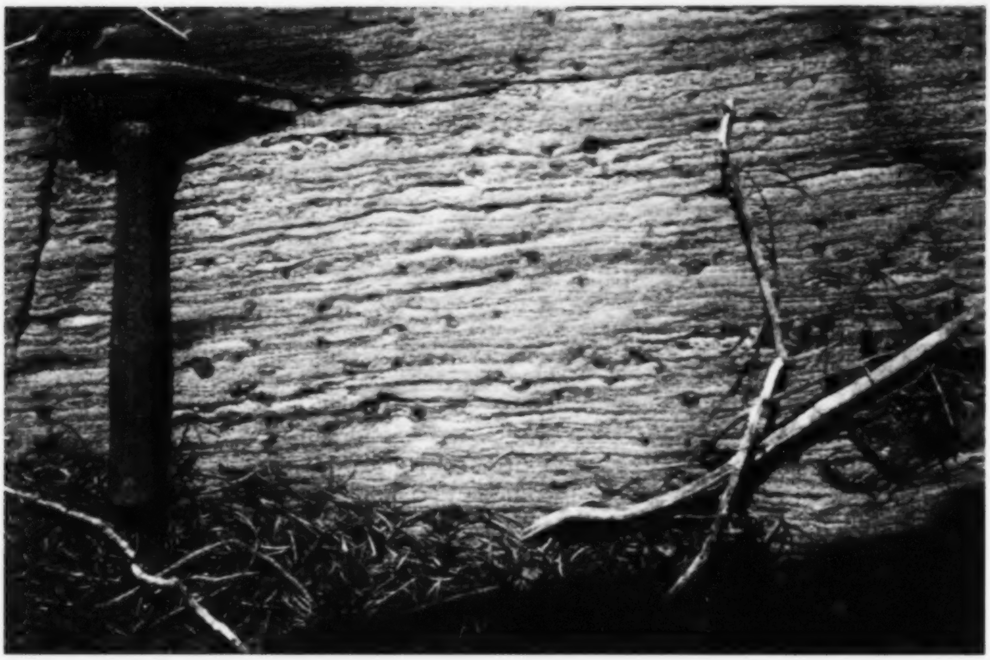


Photo 7. Typical leucosome-poor, flattened, migmatitic quartzofeldspathic, garnet-rich, gneiss of the Street gneiss association. Hammer handle is 30 cm long. Station 02RME-0530. UTM 534238E 5162562N.

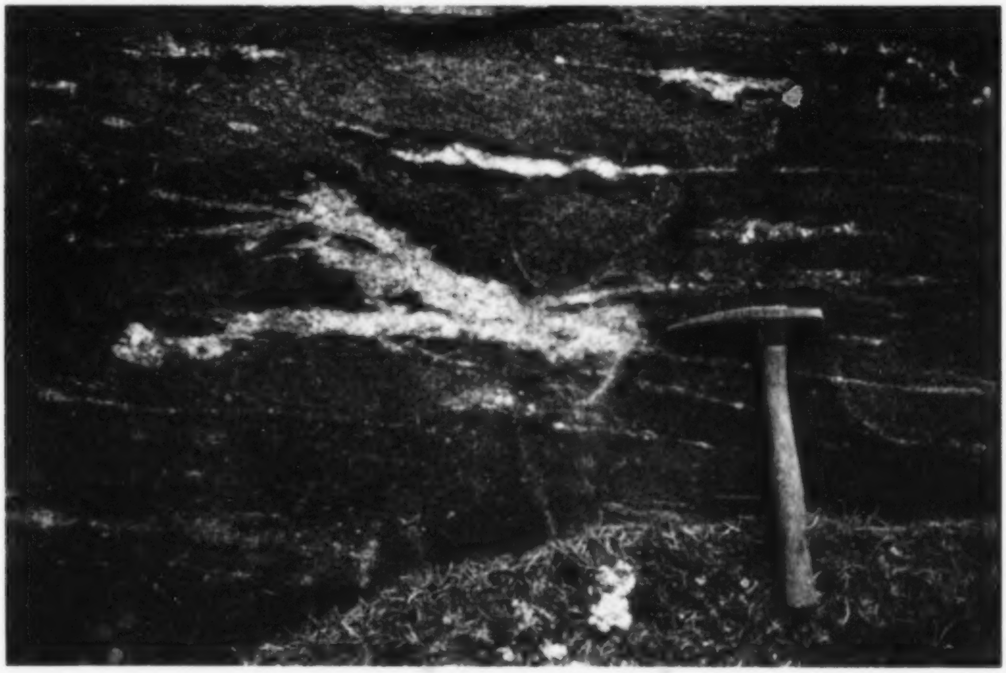


Photo 8. Typical mafic gneiss within the Street gneiss association. Note the prominent leucosome phases parallel to and discordant to gneissosity that serve to distinguish these older mafic gneisses from mafic rocks of the River Valley intrusion (compare with Photo 26a). Hammer handle is 30 cm long. Station 02RME-0468. UTM 539522E 5157621N.

FRONT GNEISS ASSOCIATION

The Front gneiss association (Easton 2002b) crops out only in northern Henry, Loughrin and Street townships, and is restricted to the area between the Grenville Front and the northernmost belt of East Bull Lake intrusive suite rocks. Although there are some similarities between the Front gneiss association and rocks observed near the Grenville Front in adjacent Street Township to the east (Easton and Murphy 2002), there are some notable differences in Loughrin Township, including the following:

1. the presence of Sudbury diabase dikes
2. the presence of a zone of highly flattened "straight gneisses"
3. a greater abundance of granitic and diorite gneiss. These rock types are described in greater detail in the sections on "Felsic Intrusive Rocks" and on the "Nipissing Intrusive Suite"; and
4. fewer identifiable Huronian Supergroup metasedimentary rocks. These rocks are described in greater detail in the section on the "Huronian Supergroup".

Rocks of the Front gneiss association in southern Janes Township are not well exposed, and were not studied in detail. The proportion of amphibolitic rocks and intrusive rocks in the Front gneiss association appears to increase east from Street Township, and based on limited observations by the author, this trend toward an increasing abundance of intrusive rock also appears to be present in northern Henry and southern Janes townships. Dressler (1979) did not report any recognizable sedimentary features from rocks of the Front gneiss association that he observed in southern Janes Township.

A 100 to 200 m wide, east-northeast-trending belt of straight gneiss approximates the boundary between the Front and Street gneiss associations. This straight gneiss belt consists of medium to thickly layered, garnet-bearing, mafic, intermediate and felsic composition rocks that can be traced from Simpson Lake, through Jones Lake (where good exposures occur on the southeast and northeast shore) and into Davis and Janes townships just north of Henry Lake. North of Henry Lake, the straight gneiss belt appears to include deformed equivalents of leucogabbronitic rocks of the East Bull Lake intrusive suite, an observation also made by Newman (1996). This straight gneiss belt may represent the continuation of a zone of straight gneiss observed in southwestern Street Township (Easton and Murphy 2000, 2002) west of the Upper Wanapitei River fault. The straight gneiss belt appears to have been structurally removed due to faulting along the Grenville Front boundary fault in Street Township, and also possibly due to exposure of a different structual level in the Timmins Creek area. It is possible that the straight gneiss belt in the northeast corner of Street Township and the northwest corner of Loughrin Township is obscured due to the extensive presence of felsic intrusive rocks in the area. It is not known if this is because the felsic intrusive rocks are younger than development of the straight gneiss belt, or that it simply becomes more difficult to identify intense deformation in these more homogeneous, fine-grained, generally thickly lichen-covered rocks.

INTERPRETED GEOLOGICAL HISTORY AND TECTONIC SETTING

Geochronological data for the Hagar—River Valley—Temagami area are summarized in Table 4. Although the data are scattered and of varied reliability, it suggests that the Archean rocks in this area record a sequence of magmatic and metamorphic events similar to that observed in the Levack Gneiss complex; the higher-grade portions of the Quetico Subprovince (e.g., Manitouwadge area); and the Ashuanipi Subprovince in Quebec. Based on existing information, the sequence and timing of events does not indicate a linkage with the Pontiac Subprovince, as previously suggested (e.g., Lumbers 1978).

Table 4. Correlation chart for Archean metasedimentary and high-grade gneiss domains located in the central and southern Superior Province, Ontario and Quebec. All ages in Ma.

	Superior Province		**Superior, Southern and Grenville Provinces**		
Event	**Pontiac Subprovince, Quebec-Ontario (metasedimentary)**	**Quetico Subprovince, Ontario (metasedimentary)**	**Elliot Lake area, Ontario (unknown type)**	**Levack Gneiss Complex, Ontario (high-grade gneiss)**	**Hagar-River Valley-Temagami area, Ontario (unknown type)**
Syenite, ne-syenite	◆	◆?	no data	◆?	no data
Late, high-level granitic rocks	2632[14]	◆?	no data	2642±1[3] Cartier Granite	~2640[17] Ma, alkali feldspar granite
Migmatization	◆	◆?	no data	2647±2[1], ~2643[2]	2647±12[7], (Ingall Lake batholith)
Granulite facies metamorphism	◆	2650±2[11], 2651±3[11]	2641, reset titanite[1]	2648±1[2]	
Pegmatite	◆	2653^{+3}_{-4}[10]	no data	no data	2650±4[5], 2660[6]
Monzodiorite, syenite, ± ne-syenite	◆	2671±2[10], 2665±2[10], 2677±5[15]	2665±2, Parisien Lake syenite[1]	2657±3[2]	younger than migmatization of tonalite and paragneiss
Pegmatite	~2668[13], 2663±1[13]	◆	◆	◆	◆
Synmetamorphic tonalite-granodiorite plutonism	◆	2669±3[9]	2676±11[16]	2681-2669[2]	~2660[17] mega-crystic grano-diorite; 2669±4[4] (Tilden pluton)
Migmatization, granulite facies metamorphism	~2665-2677	2665-2680[9,10] 2661±1[11]	no data	2661±1[2]	no data
Monzodiorite, syenite, pegmatite	2685±3[13], 2681±2[13], 2680±1[13], 2686[14], 2678[14], 2669[14]	◆	◆	◆	◆
Tonalite-granodiorite plutonism	2673±4[13] to 2695±2[13]	2688±4[12], 2689±2[9], 2687±19[10]	no data	2681-2669[2]	2678-2683[4] (Warren pluton)
Early tonalite-granodiorite plutonism	◆?	◆?	2697±12[16]	2711±7[1]	2730±2[4] (Ingall Lake batholith)
Youngest detrital zircon in paragneiss	2698, 2696, 2694, 2688, 2687, 2677[13, 8] (Pontiac, Cadillac, Timiskaming groups)	2690, 2692[8,9], 2687[10]	not applicable?	not applicable	no data
Paragneiss provenance	3029, 2980, to 2760, most <2725[13, 8]	3350, 2900, 2700[12,10]	not applicable?	not applicable	no data

[1] Krogh, Davis and Corfu 1984, [2] Wodicka and Card 1995, [3] Meldrum et al. 1997, [4] Chen, Krogh and Lumbers 1995, [5] Krogh 1994, [6] Krogh and Davis 1970, [7] Steiger and Wasserberg 1969, [8] Davis 1992, [9] Zaleski, van Breemen and Peterson 1999, [10] Percival and Sullivan 1988, [11] Pan, Flett and Heaman 1998, [12] Davis, Pezzutto, and Ojakangas 1990, [13] Mortensen and Card 1993, [14] Machado et al. 1991, [15] Kwon, Tilton and Grunenfelder 1989, [16] Prevec 1993, [17] this study.

◆ event not present, ◆? event may not be present.

The following geological history is inferred. After deposition of a greywacke succession south of the Temagami greenstone belt, invasion by tonalitic to granodioritic plutons, probably accompanied by burial, formed the migmatitic gneisses now represented by the Pardo and Red Cedar Lake gneiss associations. These events likely occurred in a short interval, between 2685 and 2675 Ma. This was followed by a renewed period of tonalitic to granodioritic magmatism, deformation and regional metamorphism, possibly at mid-crustal levels, between 2670 and 2660 Ma. The Crerar gneiss association may represent the products of this latter event. Subsequent granitic to syenitic magmatism occurred at roughly 2640 Ma, and was accompanied by emplacement of pegmatite veins.

INTERPRETED CRUSTAL SECTION IN THE STUDY AREA

Percival et al. (1992) described the general features of exposed crustal cross-sections. A logical extension of this work is the interpretation of the three gneiss associations in the River Valley area as a southward-deepening section of the crust, as illustrated in Figure 4. Exposure of this section is likely the result of north-northwest-directed transport along Grenville-age thrust faults. As interpreted herein, Archean metawackes exposed immediately north of the Grenville Front represent high levels in the crust. Rocks of the Pardo gneiss, immediately south of the Grenville Front, represent the middle to lower part of a 10 to 15 km thick upper crustal layer dominated by supracrustal and intrusive rocks. Rocks of the Front gneiss association represent the middle portion of this upper crustal layer, and are dominated by Proterozoic rocks. Rocks of the Red Cedar Lake gneiss and the Street gneiss association represent the basal portion of this upper crustal layer, with the Red Cedar Lake gneiss being derived from a metasedimentary rock dominated sequence, and the Street gneiss association being derived from a greenstone sequence. Tonalitic to granodioritic rocks of the Crerar gneiss association represent part of a 10 to 15 km thick middle crustal layer. This crustal section would be roughly equivalent to the section observed from west to east across the Wawa gneiss domain of the Superior Province (e.g., Moser et al. 1996). Figure 4 also indicates possible levels in the crust at which mafic intrusive rocks of the East Bull Lake intrusive suite were emplaced (see further discussion under "Depth and Mechanism of Emplacement").

Paleoproterozoic

MATACHEWAN DIABASE DIKE SWARM

Mafic rocks related to the Matachewan diabase dike swarm in the study area were only observed north of the Sturgeon River. These rocks occur both as dikes and as irregularly shaped bodies. Diabase dikes, ranging from 2 to 5 m in width, intrude the Pardo gneiss association east of Dana Lake, and the River Valley intrusion in southwestern Dana Township. Dikes that intrude the Pardo gneiss are relatively undeformed, but have been affected by regional amphibolite facies Grenvillian metamorphism. These dikes cut leucosome in the Pardo gneiss, suggesting that the main migmatization event in the gneiss occurred prior to ~ 2475 Ma. Diabase dikes, chemically correlated with the Matachewan swarm that cut the River Valley intrusion, were only observed in foliated to gneissic gabbronorites and leucogabbronorites that crop out in low areas between hills cored by better-preserved rocks of the River Valley intrusion. The dikes in these areas are more deformed than those observed in the Pardo gneiss. It is possible that areas of the River Valley intrusion intruded by dikes were more susceptible to fluid infiltration and deformation during Grenvillian regional metamorphism.

Green-weathering, plagioclase-phyric to glomeroporphyritic metabasalt occurs as irregularly shaped bodies cutting leucogabbronorite and anorthosite of the River Valley intrusion in western Dana Township within the Southern-Grenville province boundary zone (Easton and Hrominchuk 1999, 2001b). The largest of these bodies has a strike length of up to 500 m, and a thickness of up to 150 m. It was not possible in the field to determine if these bodies were intrusive or whether they represented mafic flows intruded by, or emplaced on, the intrusion. No primary volcanic textures were observed in these bodies. Geochemical study of both the dikes and the irregularly shaped bodies (e.g., Easton and Hrominchuk 1999, samples 99RME-0031, 99RME-0355, 99RME-2118, 99RME-4008, Appendix 2) (Figure 5c) indicates that they show all of the chemical features of the Matachewan diabase dike swarm (Halls and Bates 1990).

HURONIAN SUPERGROUP

North of Grenville Front

Low metamorphic grade metasedimentary rocks of the Huronian Supergroup, unaffected by Grenville deformation, only occur north of the Grenville Front in the study area. Throughout the study area, immediately adjacent to the Grenville Front, Huronian Supergroup strata consists mainly of feldspathic litharenites of the Mississagi Formation and overlying argillites and pebbly, matrix-supported, conglomerate of the Gowganda Formation (Lumbers 1973; Easton 2001). Nipissing gabbro sills intrude both formations, north of the Grenville Front. Decriptions of the Huronian Supergroup strata adjacent to the study area can be found in Debicki (1990) and Easton and Murphy (2002).

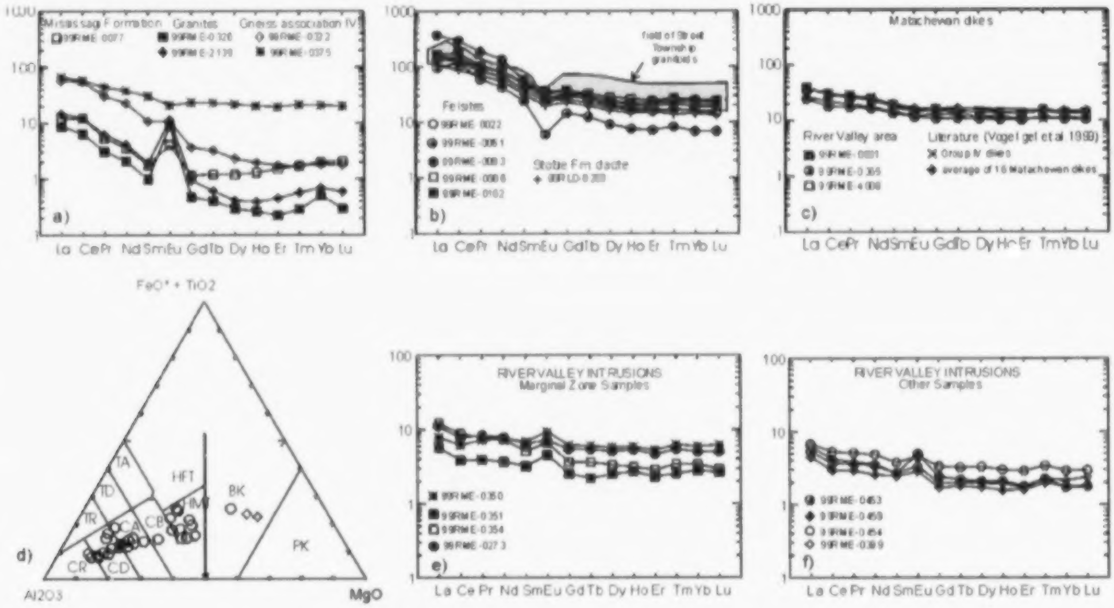


Figure 5. a) Chondrite-normalized rare earth element plot for feldspathic litharenite of the Mississagi Formation, alkali-feldspar granites, and rocks from the Crerar gneiss association. Note the prominent positive Eu anomaly in both the alkali-feldspar granites and the Mississagi Formation samples. See text for further discussion. **b)** Chondrite-normalized rare earth element plot for felsites from Dana Township. A Stobie Formation dacite and the field for Street Township granitioid rocks (*from* Easton 1998) are shown for comparison. **c)** Chondrite-normalized rare earth element plot for feldspar-phyric dikes and intrusive masses related to the Matachewan dike swarm from Dana Township. Average Group IV and Matachewan dikes from Vogel et al. (1999) are shown for comparison. **d)** Jensen diagram for samples from the River Valley intrusion, Dana-Crerar area. **e)** Chondrite-normalized rare earth element plot for gabbros from the marginal and inclusion zones of the River Valley intrusion in Dana Township. **f)** Chondrite-normalized rare earth element plot for rocks above the marginal and inclusion zones of the River Valley intrusion in Crerar Township.

In western Janes and McNish townships, Dressler (1979) assigned feldspathic litharenites located immediately adjacent to the Grenville Front to the Lorrain Formation, even though the detailed descriptions presented in his report (Dressler 1979, p.20) are more consistent with descriptions of the Mississagi Formation (e.g., Debicki 1990). Furthermore, Bruce (1932) argued that the feldspathic litharenites lay stratigraphically beneath the Gowganda Formation, inconsistent with assignment to the Lorrain Formation. In contrast, Lumbers (1973), Davidson (1986) and Easton and Hrominchuk (1999, 2001b) all assigned these same feldspathic litharenites to the Mississagi Formation. Assignment to the Mississagi Formation is supported on geochemical grounds, as the feldspathic litharenites in this area along the Grenville Front contain the low total REE contents (19.8 ppm) and positive Eu anomalies ($Eu/Eu^* = 2.7$) previously identified in some beds of the Mississagi Formation in Falconbridge and Street townships (Easton and Hrominchuk 1999; Easton and Murphy 2002) (Figure 5a).

Southern-Grenville Province Boundary Zone

For the purposes of this report, the region between the Grenville Front as shown by Easton (2001) and Easton and Hrominchuk (1999, 2001b) and the Grenville Front boundary fault, as shown by Lumbers (1973), will be referred to as the Southern-Grenville province boundary zone. This zone includes rocks of the Southern Province that have been subjected to Grenvillian regional metamorphism (Easton and Murphy 2002) as well as a variety of sheared to mylonitic rocks (Davidson 1986; Easton and Hrominchuk 1999). Description of the boundary zone is divided into 2 segments. The first is an east-trending segment present along the Kabikotitwia and Sturgeon rivers, and includes rocks found in Davis, Janes, Loughrin and Street townships. The second is a north-trending segment present along the boundary between Janes and Dana townships.

EAST-TRENDING SEGMENT

This segment has been best studied in the Timmins Creek area of Street Township (Murphy 2001; Easton and Murphy 2002), and the reader is referred to those reports for further details. Most significantly, the Timmins Creek area contains amphibolites and felsic metavolcanic rocks that are correlated with the Stobie Formation of the Huronian Supergroup, in addition to metasedimentary rocks correlative with the Pecors and Mississagi formations.

Lumbers (1973) indicates that east of Street Township, the eastern segment of the boundary zone consists mainly of metasedimentary rocks of the Mississagi Formation, as well as amphibolites which he assigned to the Nipissing intrusive suite. Given that amphibolites and felsites that represent Huronian Supergroup metavolcanic rocks occur in both Street and Dana townships, the presence of as yet unidentified Huronian Supergroup mafic and felsic metavolcanic rocks in southern Davis and Janes townships is likely.

NORTH-TRENDING SEGMENT

The southern part of the boundary zone in the vicinity of Dana Township is dominated by a variety of felsites, ranging in composition from andesite to rhyolite, with dacite predominant. Several textural varieties are present within this unit, including thick-bedded, volcanic tuff (Photo 9 and 10); lapilli tuff; quartz-feldspar porphyry; and fine-grained intrusive rocks, some of which incorporate blocks of felsic volcanic material. The dacitic and rhyolitic rocks are interlayered with layers of brown-weathering, dark, fine-grained andesites. The felsite unit is commonly cut by flinty, black, ultramylonites. In the field, it is sometimes difficult to distinguish between the mylonites and less deformed rocks if volcanic or igneous textures are not well developed or exposed; however, in thin-section the mylonitic rocks are readily distinguished from the preserved porphyry and tuffaceous units. The felsite unit continues west into Janes Township, where Lumbers (1973) and Dressler (1979) mapped them as differentiates of the Nipissing gabbro. This interpretation seems unlikely given the localized presence of pyroclastic and porphyritic textures, as well as the large volume of these rocks within southeastern Janes and southwestern Dana townships.

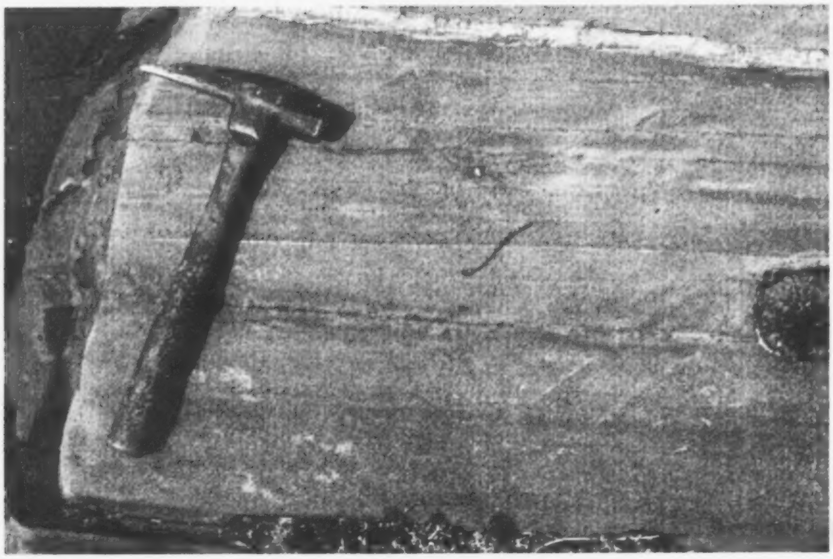


Photo 9. Bedded rhyodacite tuff to crystal tuff, Huronian Supergroup, Grenville Front area near Glen Afton, Dana Township. Hammer handle is 30 cm long. Station 99RME-0022. UTM 553942E 5166294N.

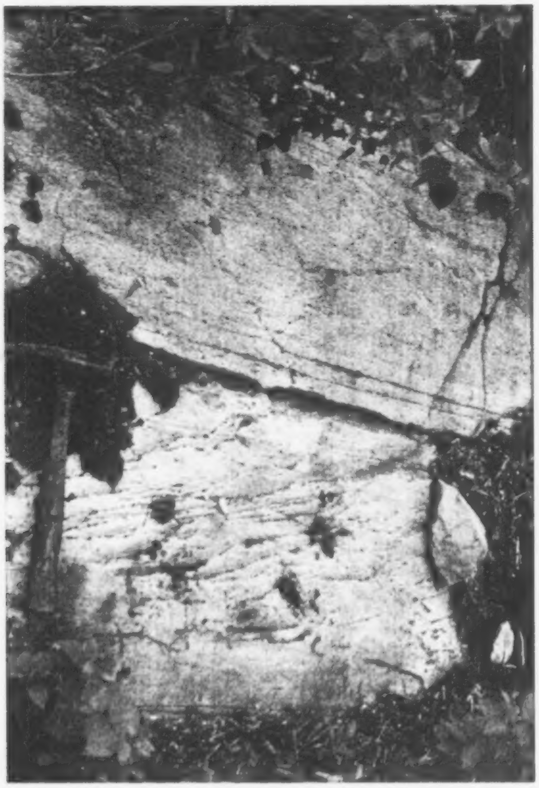


Photo 10. Cross-bedding in bedded rhyodacite crystal tuffs (subaqueous pyroclastic flows), Huronian Supergroup, Grenville Front area, west of Highway 805, Dana Township. Hammer handle is 30 cm long. Station 99RME-0087. UTM 554118E 5168554N.

As outlined in Easton and Hrominchuk (1999), geochemistry of these felsites (samples 99RME-0022, 99RME-0083, 99RME-0086, 99RME-0162, Appendix 2) indicate that they are related to dacitic rocks of the Stobie Formation in Falconbridge Township (Figure 5b), and dacitic and granitic rocks previously described by Easton (1998) in Street Township (sample 96RME-0124, Appendix 2). All these felsic rocks are tholeiitic, and are characterized by FeO^{total} >3.5%, CaO >1.5%, Eu/Eu* 0.55-0.77, La/Yb 5-10, Gd/Yb 1.2-2, Zr/Y 5-7.5, Zr 200-790, Y 35-110, TiO_2 0.3-1.0, Sr 80-210, all features of FIIIb type rhyolites. In the Archean, FIII rhyolites are typically associated with volcanogenic-massive sulphide (VMS) deposits (e.g., Parker and Ayer 1997), however, this association does not consistently apply to non-Archean rocks. Corfu and Easton (2000) dated associated granitoid rocks from Street Township at 2460±20 Ma, consistent with field relations suggesting that the Street Township felsites are older than the Mississagi Formation. Based on the geochemical similarity, and the fact that the rocks in Dana Township occur roughly on strike with those present in Street Township, Easton and Hrominchuk (1999, 2001b) assigned these felsites to the lowermost Huronian Supergroup.

As part of this study, an attempt was made to extract zircon from an undeformed dacite located within the boundary zone in Dana Township for the purposes of dating these felsites (Photo 10). The sample in question did not yield any zircon, however, a small quantity of titanite was obtained from the sample, which yielded a preliminary $^{207}Pb/^{206}Pb$ age of ~1865 Ma but with a large error (±200 Ma) (S. Kamo, Geochronologist, Jack Satterly Geochronology Laboratory, Royal Ontario Museum, unpublished data, 2003). The significance of this age is unclear; it could reflect the age of Penokean deformation and metamorphism in the Southern Province.

In the boundary zone, the felsites appear to be directly overlain by argillite and pebbly conglomerate of the Gowganda Formation, without the intervening Mississagi Formation. A less tectonized outcrop on Highway 805 (UTM 17, 554065E, 5170273N), sandwiched between mylonite zones, contains large angular blocks of fine-grained granite in a fine-grained clastic matrix, and may represent an unconformity between the felsite unit and the overlying Huronian metasedimentary rocks (Photo 11).

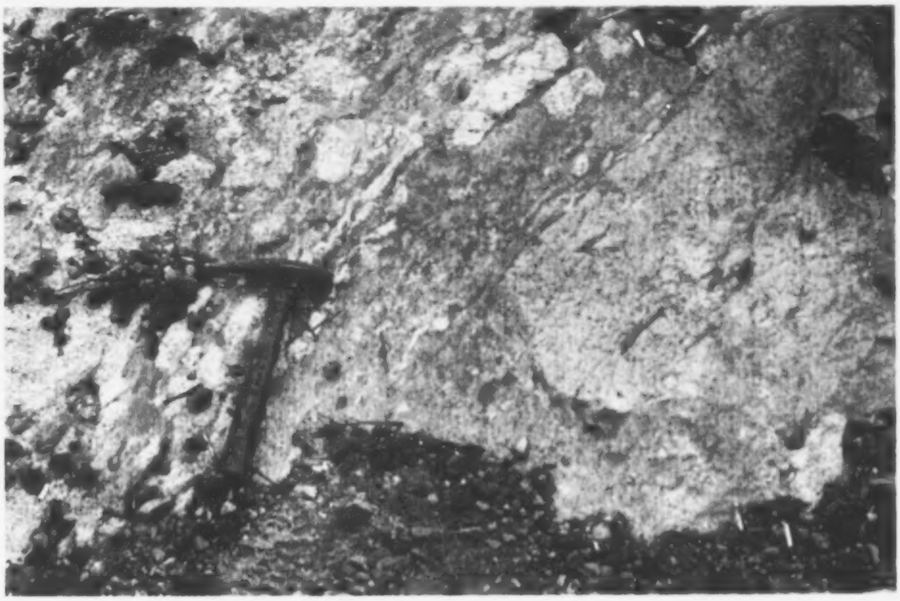


Photo 11. Coarse polymictic conglomerate (left, above hammer) developed atop fine-grained gneissic granite (right), preserved in a window within the Grenville-Southern province boundary zone along Highway 805 in west-central Dana Township. Hammer handle is 30 cm long. Station 99RME-0069. UTM 554064E 5170274N.

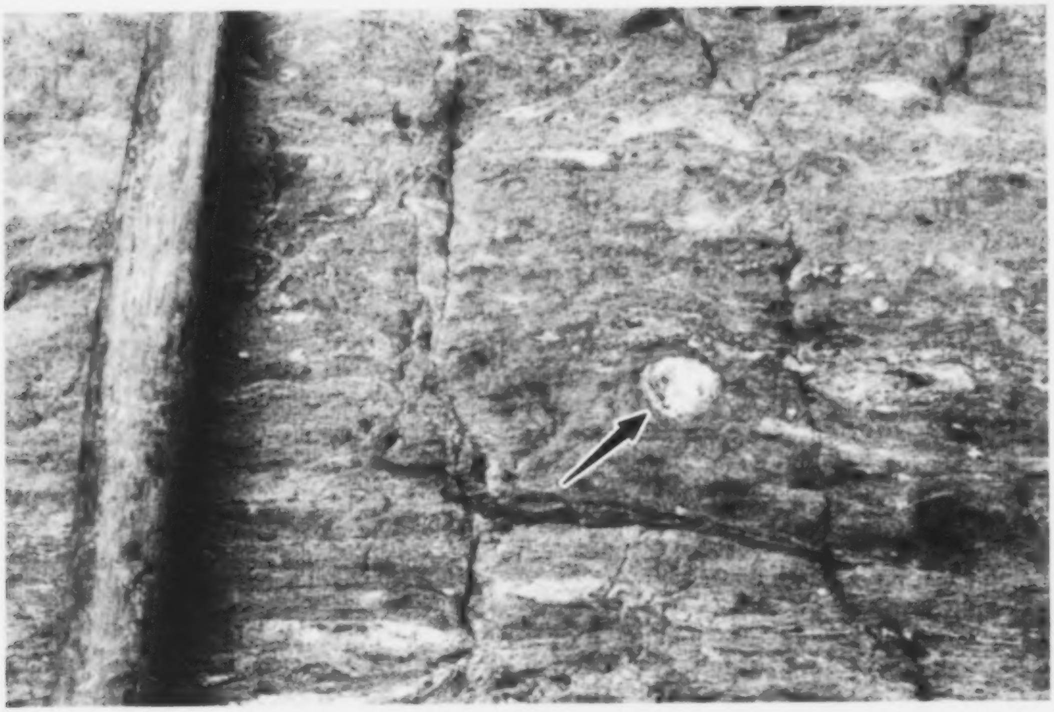


Photo 12. Ultramylonite within a Grenville Front bounding fault in Dana Township. Large feldspar porphyroclast near centre may be derived from coarse-grained anorthositic rocks of the River Valley intrusion. Station 99RME-0250. UTM 555672E 5172060N.

Both the felsites and the Gowganda Formation are intruded by Nipissing gabbro sills, which show the high-magnesium signature common to the Nipissing suite in the area east of Sudbury (samples 99RME-0023, 99RME-0024, Appendix 2). Ultramylonites within the boundary zone are compositionally varied. In some localities, they are clearly derived from anorthositic phases of the River Valley intrusion (Photo 12), elsewhere, they are derived from the felsite unit and Nipissing gabbro.

The boundary zone also contains rocks of the River Valley intrusion. It should be noted that the River Valley intrusion in the boundary zone is cut by felsite dikes (sample 99RME-0061, Appendix 2); feldspar-phyric mafic dikes that are chemically similar to the Matachewan dike swarm (2446 Ma) (sample 99RME-4008, Appendix 2); and Nipissing gabbro (2220 Ma) (sample 99RME-0024, Appendix 2). This is the only known area where all these crosscutting relationships are observed; possibly a manifestation of the structural level of the intrusion exposed in this zone. Sudbury swarm diabase dikes also occur within the boundary zone, but were only observed intruding rocks of the Gowganda Formation.

A regional alteration zone, roughly 9 km long and 2 to 3 km wide, stretches roughly from Dana Lake east-northeast into Pardo Township (Lumbers 1973, Easton 2001). This zone is marked by the widespread development of chlorite and sericite and bleaching in the host lithologies, and occurs adjacent to, or straddles the Grenville Front. Alteration affects all rock units within this zone. Lumbers (1973) identified this zone on his map using sub-unit letter codes as a zone of greenschist facies metamorphism and cataclasis. The significance of this zone is uncertain; however, given its localized occurrence and the fact that it affects all rock types, it may be related to fluid movement along the Grenville Front. The author did not prospect this zone, as much of it is located out of the study area, but it could have economic potential, possibly for gold.

South of Grenville Front

Few rocks belonging to the Huronian Supergroup have been identified south of the Grenville Front in the study area, and of those that have, almost all occur no more than 3 km south of the Grenville Front, and almost all occur within the Front gneiss association.

In western Street Township, Easton and Murphy (2002) identified metawacke and kyanite- and garnet-bearing metapelite horizons that showed a geochemical affinity to the Pecors Formation. In northeastern Street Township, Easton and Murphy (2002) identified several metawacke, kyanite- and garnet-bearing metapelite, white-mica schist and metaconglomerate horizons. The metawacke, metapelite and schist showed geochemical affinities to the Pecors and Mississagi formations, whereas the metaconglomerate could be assigned geochemically to either the Stobie or the Ramsay Lake formations. These geochemical correlations are plausible, as all of the geochemically identified formations occur at or near the base of the Huronian Supergroup as it is recognized in the area east of Lake Wanapitei (Debicki 1990; Easton and Murphy 2002). In addition, all of the potential Huronian Supergroup rocks identified in the Timmins Creek area of Street Township crop out in the Southern Province within 1 kilometre or less of the Grenville Front. Furthermore, mafic intrusive rocks that can be geochemically correlated with the Nipissing intrusive suite, as well as Paleoproterozoic felsic intrusive rocks, occur in association with the metasedimentary rocks that have been correlated with the Huronian Supergroup.

In Loughrin Township, identifiable metasedimentary rocks, most likely belonging to the Huronian Supergroup, are common in the vicinity of Simpson Lake. These rocks form the eastward continuation of a belt of metapelite, metawacke and metaconglomerate present in the Timmins Creek area of northeastern Street Township. These metasedimentary rocks are variably migmatitic, with the degree of migmatization possibly reflecting original compositional differences in the metasedimentary sequence. Locally, pockets of non-migmatitic rocks showing relict primary textures are preserved. The largest of these pockets occurs on the north shore of Simpson Lake, where a 50 m wide belt of matrix-supported, polymictic metaconglomerate containing small (1 to 5 cm size) clasts in a fine-grained, typically garnet-bearing, matrix can be traced over 500 m along the north shore of Simpson Lake. This belt of metaconglomerate may continue east on strike toward Jones Lake, where Fairbairn (1939) reported the presence of metaconglomerate along the south shore of the lake. The author was unable to locate any metaconglomerate in the area shown by Fairbairn (1939), however, it is possible that the outcrops he observed are now obscured by vegetation and thick lichen cover.

The matrix of the metaconglomerate at Simpson Lake was analyzed for chemistry (sample 02RME-0613, Appendix 2, Figure 6) and it shows the geochemical signature of either the Pecors or the Ramsey Lake formations. Although there is no published rare earth element data for the Ramsey Lake Formation, the fact that the rock is a metaconglomerate, not a metasiltstone, makes correlation of the Simpson Lake metaconglomerate with the Ramsey Lake Formation the more likely choice. This is consistent with the outcrop appearance of the unit, despite metamorphism, and with observations in the Timmins Creek area to the west (Easton and Murphy 2002). The metaconglomerate is also associated with horizons of white mica-rich quartzose gneiss. The quartzose gneiss was not analyzed for chemistry, but in outcrop appearance and composition it resembles similar quartzose gneiss layers observed in the Timmins Creek area, which also occur in close proximity to the metamorphosed Huronian Supergroup strata in that area. The quartzose gneiss analyzed in the Timmins Creek area showed a distinct geochemical signature that was more consistent with an Archean rather than a Proterozoic source (Easton and Murphy 2002). On the north shore of Jones Lake are several exposures of felsite, some of which are fragmental in nature (Photo 13) and which may represent felsic metavolcanic rocks. These felsic fragmental rocks lie just to the north of the previously described straight gneiss belt that marks the boundary between the Front and Street gneiss associations (*see* "Front Gneiss Association").

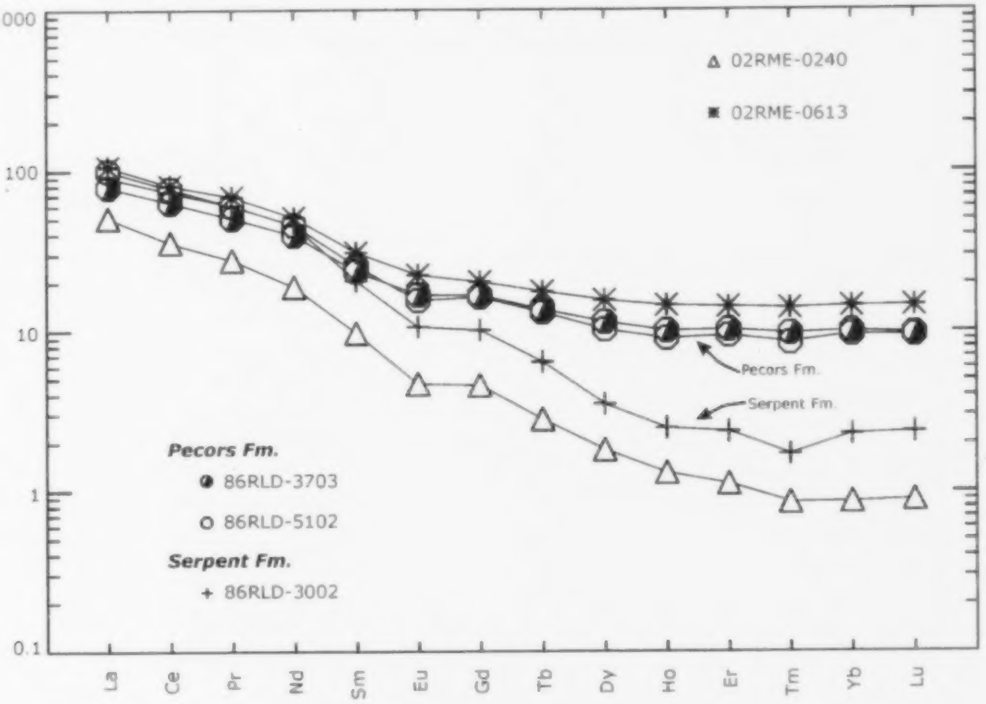


Figure 6. Chondrite-normalized rare earth element plot for metaconglomerate at Simpson Lake (sample 02RME-0613) and quartzose gneiss from Henry Township (sample 02RME-0240). Representative samples of Pecors and Serpent Formation samples are shown for comparison.

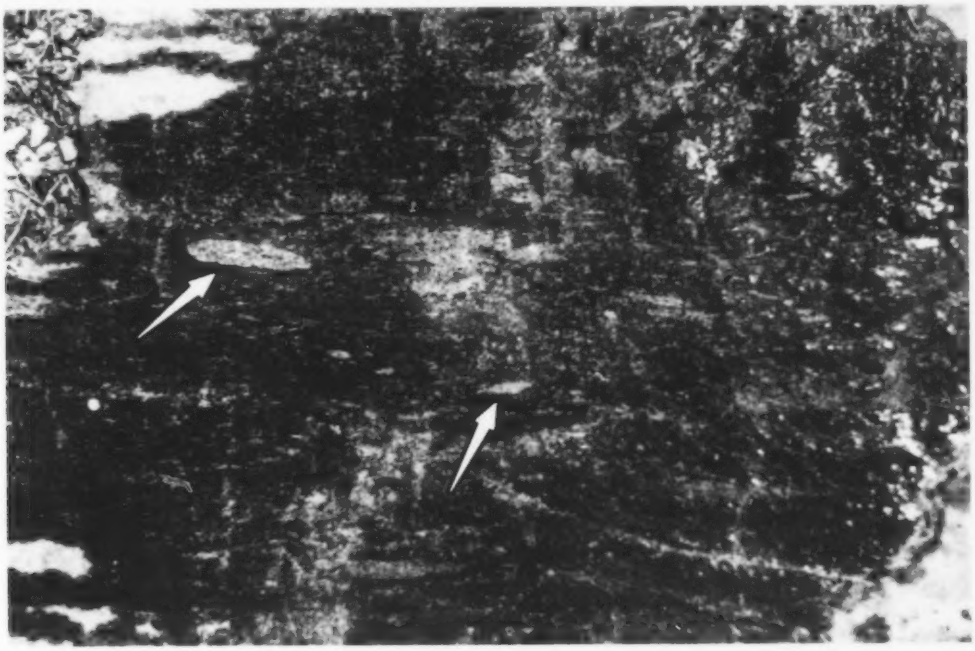


Photo 13. Fragmental felsite, possibly a metavolcanic rock, exposed in trail on north shore of Jones Lake. Arrows point to representative fragments. Station 02RME-0066. UTM 535494E 5163304N.

The only possible Huronian Supergroup rock that occurs exclusive to the Front gneiss association is present as a large inclusion, up to 50 m in size, of quartzose gneiss that is found within an intrusion of gneissic granite likely of Proterozoic age present in southeastern Henry Township. The gneissic granite also contains large inclusions of gabbroic rocks similar in appearance to the East Bull Lake intrusive suite, also suggesting a Proterozoic age for the gneissic granite. The gneissic granite occurs in the area underlain mainly by country rocks of the Crerar gneiss association.

The quartzose gneiss was analyzed for chemistry (sample 02RME-0240, Appendix 2, *see* Figure 6), and shows a close geochemical affinity to quartz arenite of the Serpent Formation of the Huronian Supergroup. If the quartzose gneiss was derived from the Serpent Formation, then 3 explanations are possible. First, it could indicate that at one time, rocks of the Serpent Formation were located at least 15 kilometres south of the present Grenville Front, and have been subsequently eroded during uplift associated with the Grenville orogeny. Alternatively, it is possible that rocks of the Serpent Formation underlie this part of the Grenville Province, and became entrained within the granitic magma during its emplacement. There is also a third possibility, namely that the quartzose gneiss is not correlative with the Serpent Formation, and represents an unkown metasedimentary sequence present in the study area.

FELSIC INTRUSIVE ROCKS

Bodies of foliated to gneissic monzogranite and granodiorite occur throughout the Grenville Province within Henry, Loughrin and Street townships. These rocks occur on both sides of the Grenville Front boundary fault, but are more commonly observed within the Grenville Province. This apparent abundance in the Grenville Province may simply reflect erosion level. Felsic intrusions of this suite appear to be restricted to the Front and Street gneiss associations. One of these felsic intrusions on the boundary road between Henry and Loughrin townships has been examined as a potential building stone (Sawitzky 1994).

The granitoid bodies commonly occur in the cores of regional antiforms related to F_2 folding in the study area and are generally surrounded by garnet-biotite migmatitic gneisses. The presence of these rocks in the core of folds, as well as their migmatitic character, was originally interpreted as an indication that they may have been basement to the surrounding garnet-biotite migmatitic gneisses (Davidson 1998; Easton and Murphy 2002). Subsequent geochronology, however, indicates that these intrusive rocks are early Paleoproterozoic in age and younger than the host migmatitic gneisses (Corfu and Easton 2000).

In Henry and Loughrin townships, the felsic intrusive bodies can be divided into 2 types on the basis of both surface map pattern and aeromagnetic patterns. Both types are characterized by aeromagnetic highs, with associated resistivity lows. The first type forms linear map and magnetic patterns, the second type is ovoid. Ovoid bodies are only found in central Loughrin and Henry townships within the Street gneiss association. Elongate bodies occur throughout Street, Loughrin and Henry townships, and are hosted by rocks of the Front gneiss association, or occur along the southern and northern contacts of the Street gneiss association. In terms of petrography and geochemistry, however, there appears to be no discernable difference between the ovoid and elongate types. It is not known if the different shapes of the felsic intrusions reflect 1) a difference in emplacement age, with the ovoid-type being younger, or 2) differences in deformation history between intrusions of the same age. In the latter case, the elongate bodies would indicate areas of high, post-emplacement strain, whereas the ovoid bodies indicate areas that were subject to less post-emplacement strain, thereby retaining their original emplacement shapes.

Granitoid rocks of the suite in Street Township were dated at two localities, north and south of the Grenville Front boundary fault of Lumbers (1973), giving ages of 2460±20 Ma and $2475^{+25}/_{-10}$ Ma, respectively (Corfu and Easton 2000). These ages are identical within error limits and are consistent with field evidence in Henry, Loughrin and Street townships of incorporation of anorthositic blocks of the East Bull Lake intrusive suite (~ 2475 Ma) within felsic intrusions of the suite. The intrusions dated in Street Township also indicate that a metamorphic or resetting event occurred at roughly 1720 Ma, in addition to Grenvillian metamorphism at approximately 990 Ma (Corfu and Easton 2000).

As part of this study, a sample was collected for U/Pb dating from a felsic intrusion associated with a prominent magnetic anomaly located on the Henry-Loughrin township boundary. Interpretation of the zircon and titanite data from this intrusion is problematic. One interpretation is that the intrusion was emplaced at ~ 2450 Ma, and subjected to metamorphism at either 1860 or 1600 Ma, as well as Grenvillian metamorphism at ~ 1000 Ma. Alternatively, the intrusion could have been emplaced between Geon 18 and 19, and subjected to metamorphism at ~ 1600 and 1000 Ma. (S. Kamo, geochronologist, Royal Ontario Museum, unpublished data, 2003). In addition, there is some indication of an event at ~ 1250 Ma, which may be related to emplacement of Sudbury diabase dikes, which occur within 100 m of the sample site. Dickin (1998) collected a sample from the same intrusion, and obtained a Nd/Sm model age of 2820 Ma, consistent with the results of Smith (2002), and older than the 2710 to 2660 Ma Nd/Sm model ages obtained from rocks of the Crerar gneiss association.

One granite body in southeast Henry Township contains inclusions up to 50 m in size of gabbroic rocks similar in appearance to the East Bull Lake intrusive suite, as well as quartzite. As noted in the section on the "Huronian Supergroup", the geochemical signature of one of these quartzite inclusions indicates that it could be derived from the Serpent Formation of the Huronian Supergroup. If so, this would indicate that Serpent Formation deposition must have occurred sometime prior to ~ 2460 Ma (the age of the Street Township granitoids dated by Corfu and Easton 2000). Direct dating of the gneissic granite hosting this quartzite inclusion would be desirable in order to place a more precise limit on the maximum age of Serpent Formation, and by inference, Huronian Supergroup, sedimentation.

Felsic intrusive rocks of this suite are foliated on the north side of the Grenville Front boundary fault, but south of the boundary fault are banded migmatitic gneissic granite (Photo 14). The monzogranite to granodiorite gneiss is fine- to medium-grained, pinkish-grey and generally weathers pink. A millimetre- to centimetre-thick compositional layering is observed in many outcrops. In hand specimens, feldspar constitutes 35-50% and quartz as much as 45% of the rock. Dark-coloured minerals are biotite and hornblende, and in a few places, dodecahedral crystals of garnet up to 0.7 cm in diameter. Leucosome and 2 generations of pegmatite dikes are commonly found in the granitic gneisses south of the Grenville Front boundary fault. The leucosome and older generation of pegmatites strike parallel to regional foliation whereas the second generation of pegmatite transects the foliation.

In thin section, the major mineral phases in the monzogranite to granodiorite gneiss are plagioclase, potassium feldspar, quartz, biotite, hornblende and secondary chlorite with accessory titanite, rutile, epidote, apatite and opaque minerals. Brown-black laths of biotite and hornblende define the foliation fabric. Sub- to idioblastic garnets in metagranites have poikioblastic cores and inclusion-free rims that are indicative of syn- to post-tectonic garnet growth. The equilibrium assemblage is hornblende-plagioclase (An_{12-22})-biotite-muscovite-garnet-potassium feldspar-quartz (Murphy 2001). Coloured mica is magnesium-rich and plots in the phlogopite field on mica classification diagrams (Murphy 2001). Amphibole compositions correspond to hastingsitic hornblende (Murphy 2001).

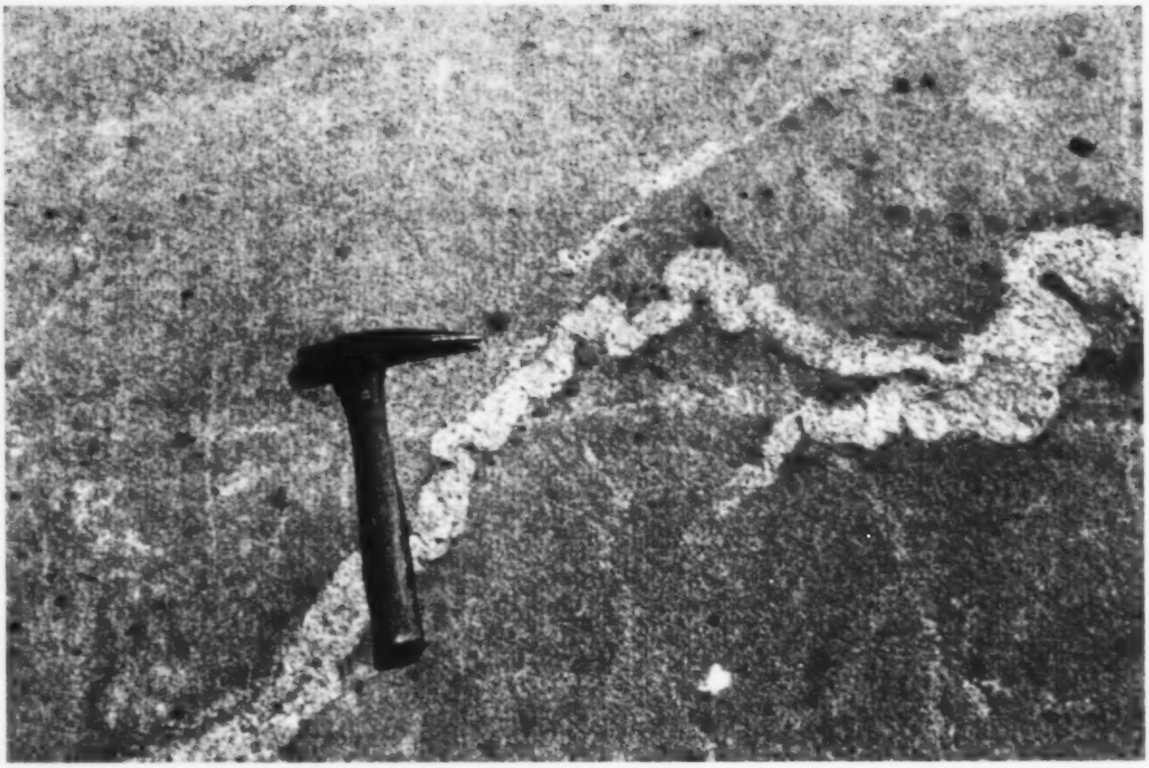


Photo 14. Thin felsic vein cutting fine-grained gneissic granite of the Geon 24 and 23 felsic intrusive suite, at a building stone prospecting pit in Loughrin Township, just west of Boundary Road. Hammer handle is 30 cm long. Station 02RME-0014. UTM 544433E 5160554N.

Geochemistry

Rocks of the felsic intrusive suite are similar in chemistry and age (Easton 1998; Easton and Murphy 2002; Corfu and Easton 2000) to felsic metavolcanic rocks of the Stobie Formation. Although similar in age to the Murray granite and felsic metavolcanic rocks of the Copper Cliff Formation, rocks of the felsic intrusive suite and related Stobie Formation felsic metavolcanic rocks in Street Township are chemically distinct (Easton 1998; Easton and Murphy 2002). Both the felsic metavolcanic rocks and the gneissic granites in Street Township are characterized by SiO_2 = 66-72 wt. %, Al_2O_3 = 11.9-12.6 wt. %, FeO^{total} greater than 3.5 wt. %, CaO greater than 1.5 wt. %, Eu/Eu* = 0.55-0.70, La/Yb = 5-8 and Gd/Yb = 1.2-1.65. On AFM and Jensen diagrams, they are tholeiitic in character, whereas data for the Copper Cliff rhyolites as well as the Murray and Creighton granites plot in the calc-alkalic field (Easton and Murphy 2002) (Figure 7). In addition, the Street Township felsic rocks plot in either the "Within-Plate" or "Rift-Related" granite fields on various geochemical discrimination diagrams (Figure 8). The Street Township felsic rocks are also chemically distinct from Neoarchean granitic rocks in the Sudbury area such as the Cartier batholith (Meldrum et al. 1997). For example, data from the Cartier batholith plots in the "Syn-collision Granite" field on a Pearce, Harris and Tindle (1984) diagram and is peraluminous whereas Street Township felsic rocks plot in the "Within-Plate Granite" field (*see* Figure 8) and are metaluminous. Other important chemical characteristics of both the Street Township felsic rocks include Zr/Y ratios of 5 to 7.5, Zr = 280-790 ppm, Y = 42-110 ppm, TiO_2 = 0.3-0.8 wt. %, Sc = 6-12 ppm, Sr = 110-210 ppm and elevated, flat rare earth element patterns with negative Eu anomalies. All of these features are typical of FIIIb type rhyolites, which are typically associated with Archean and younger volcanogenic massive sulphide (VMS) deposits (Lesher et al. 1986; Parker and Ayer 1997; Hart et al. 2001).

Smith (2002) studied the chemistry of the Creighton pluton in detail, and made additional comparisons with rocks of the Murray pluton and the Street Township gneissic granites. Smith (2002) also obtained new U/Pb ages from the Creighton pluton. The work of Smith (2002) indicated that there were 2 geochemical phases to the Creighton pluton, one emplaced at 2415±5 Ma and the other at 2376±2 Ma. This expands the range of felsic magmatism during Geon 24 in the Sudbury area from a previous range of between 2477±9 to 2450±25 (age of the Murray pluton and the Copper Cliff rhyolite, respectively, *see* Table 2) to an expanded range of between 2477±9 to 2376±2, an interval of at least 100 million years.

In addition, Smith (2002) noted that the chemistry of the felsic intrusive rocks changes with age, with older plutons having tholeiitic chemistry similar to that of the Street Township felsic rocks (A-type chemistry, Mg-number <15, Kilpatrick and Ellis 1992) and younger rocks having C-type chemistry (Kilpatrick and Ellis 1992). C-type granitoids are similar in many features to A-type granitoids, but are characterized by a lower (and wider) range in SiO_2 values, higher TiO_2, P_2O_5 and K_2O at a specfic SiO_2 level and higher Mg-number (25-40). C-type magmatism can result from the input of large volumes of basalt into lower crustal granulites with subsequent dry partial melting (Kilpatrick and Ellis 1992). Although no granulites have been found in the Grenville Front tectonic zone in the Sudbury–River Valley area, it is probable that they are present at depth (*see* Figure 4). Certainly, involvement of Mesoarchean crust is likely, as the Geon 24 and 23 felsic intrusive rocks in the Sudbury-River Valley area have Nd/Sm model ages of 2790 to 2830 Ma (Smith 2002; Dickin 1998). These Nd/Sm model ages have been interpreted as indicating involvement of older crust in the generation of these magmas (Ashwal and Wooden 1989; Smith 2002).

The observations by Smith (2002) have been confirmed by this study, and are illustrated in Figures 7 to 9. Although most of the Street Township samples show A-type chemistry, many of the felsic intrusive rocks present in Henry and Loughrin township are characterized by C-type chemistry (*see* Appendix 2 and Figures 7 to 9).

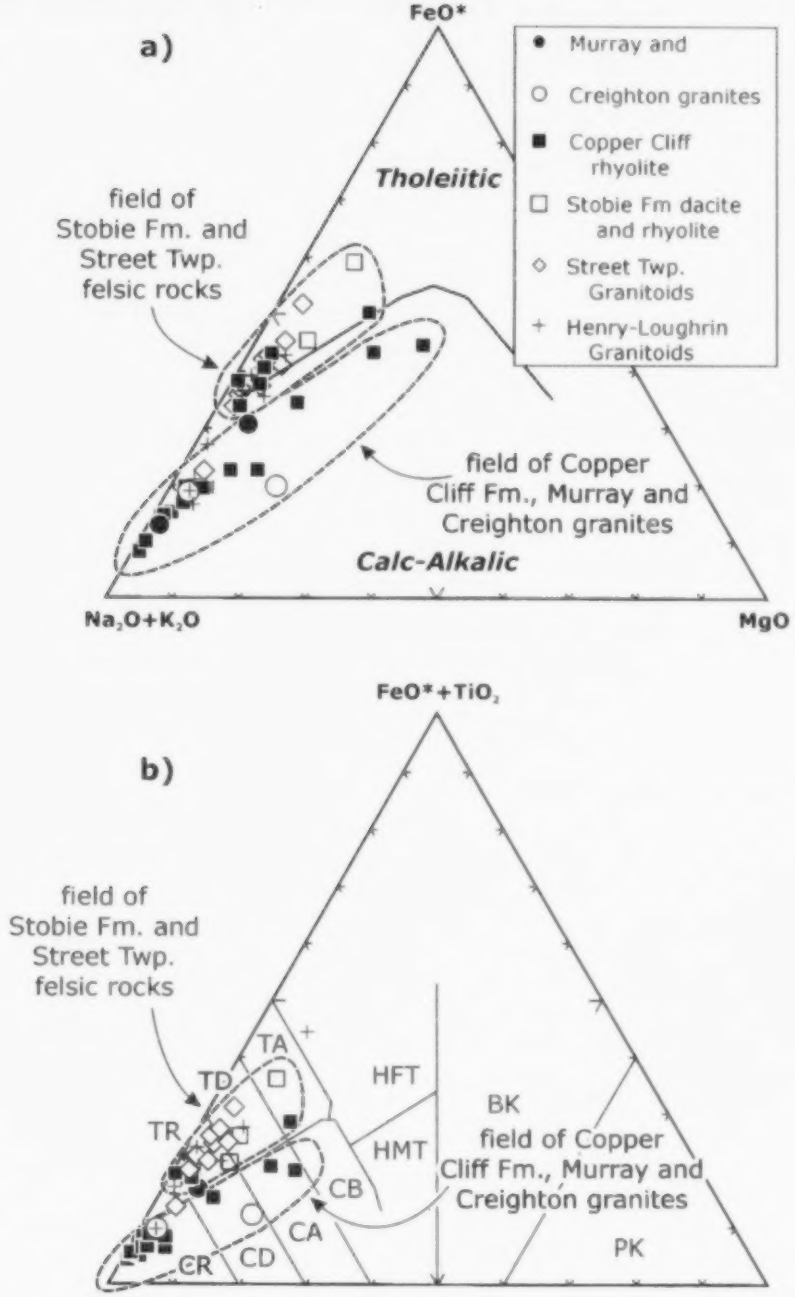


Figure 7. AFM (upper) and Jensen (lower) diagrams for felsic metavolcanic rocks of the Stobie Formation from Sudbury and Street Township, as well as data for the Street Township and Henry and Loughrin townships granitoids, the Copper Cliff Formation, and the Murray and Creighton granites. Note the felsic rocks fall into two groups. One group plots in the tholeiite field on both plots and consists of the Stobie Formation volcanic rocks, the Street Township and most of the Henry and Loughrin townships granitoids, and a limited number of Copper Cliff Formation volcanic rocks. The other group plots in the calc-alkalic field on both plots, and consists of the bulk of the Copper Cliff Formation, the Murray and Creighton granites, and the C-type Henry and Loughrin granitoids. Copper Cliff, Murray and Creighton granite data from Easton and Murphy (2002).

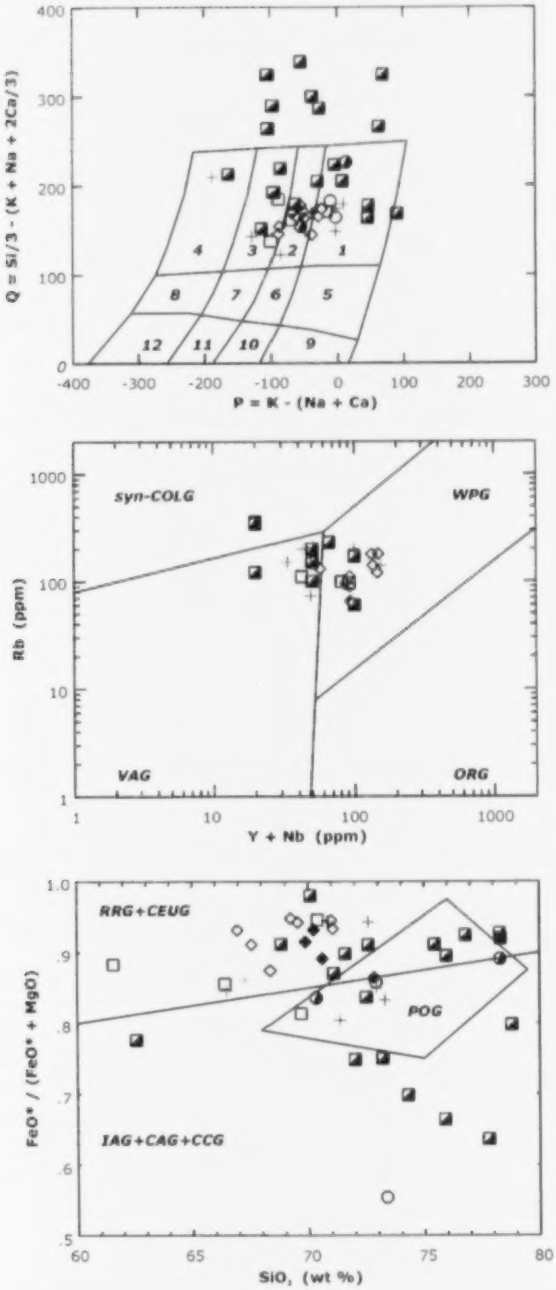


Figure 8. Granitoid classification plots of Debon and Le Fort (1983)(upper), Pearce, Harris and Tindle (1984)(middle) and Maniar and Piccoli (1989)(lower) for Huronian-age felsic intrusive and extrusive rocks using the same data as Figure 7. Symbols same as in Figure 7. Note in all plots the tight cluster of the Street and Henry and Loughrin townships granitoids. The Street and Henry and Loughrin townships granitoids classify as Within-Plate granites (WPG in middle plot) or Rift-Related granites (RRG in lower plot). Also note the scatter in the Copper Cliff Formation metarhyolites, which may result from alkali addition. Copper Cliff, Murray and Creighton granite data from Easton and Murphy (2002). Abbreviations: Upper figure, 1 = syenogranite, 2 = monzogranite, 3 = granodiorite, 4 = tonalite. Middle figure, VAG = volcanic-arc granite, syn-COLG = syn-collision granite, WPG = within-plate granite. Lower figure, RRG+CEUG = rift-related and continental epeirogenic uplift granites, IAG+CAG+CCG = island-arc, continental-arc and continental-collision granites, POG = post-orogenic granites.

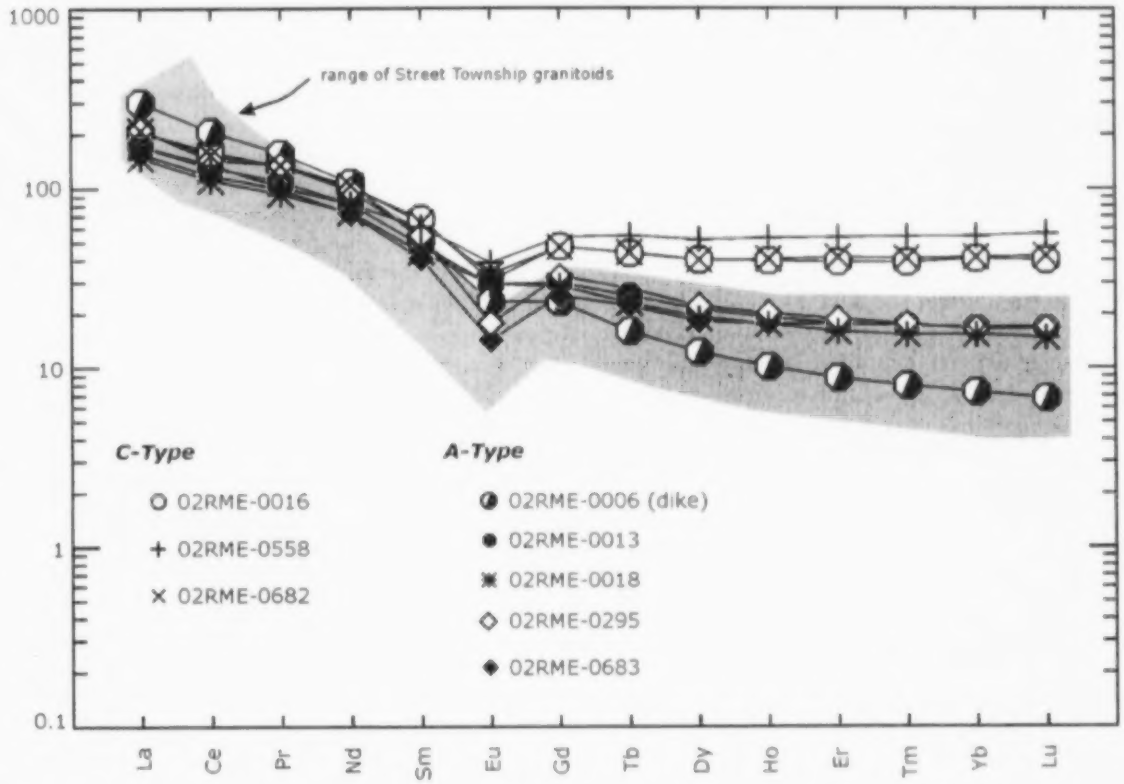


Figure 9. Chondrite-normalized rare earth element plots for granitoid rocks from Henry Township. Three of the samples show C-type chemistry, whereas 6 samples show A-type chemistry. The field for 9 samples from Street Township (Easton and Murphy 2002, Figure 29), all with A-type chemistry, is shown for comparison.

NIPISSING INTRUSIVE SUITE

Mafic Intrusive Rocks

Mafic intrusive rocks of the Nipissing intrusive suite commonly form sill-like bodies that intrude the Huronian Supergroup at a variety of stratigraphic levels but most commonly near the base of the Huronian stratigraphic succession and into the Gowganda Formation. Rocks of the suite consist mainly of gabbronorites and olivine gabbronorites, and were emplaced at ~ 2200 Ma (*see* Table 2). Rocks of the Nipissing intrusive suite were originally mapped as Sudbury gabbro, consequently, the sills are commonly referred to as Nipissing gabbro. Rocks of the Nipissing intrusive suite commonly exhibit sub-ophitic to ophitic texture, and in the past, have been termed Nipissing diabase even though the rocks are generally far too coarse-grained to be a true diabase. The study by Lightfoot and Naldrett (1996) on the Nipissing gabbro summarizes the typical petrographic, stratigraphic and geochemical characteristics of the suite, and the reader is referred to this publication for more detailed regional information.

The typical Nipissing gabbro in the Southern Province near the Grenville Front is an equigranular, fine- to medium-grained, grey to dark greenish grey weathering rock. Orthopyroxene-rich varieties tend to weather grey and possess a "sugary" recrystallized texture. In thin section, plagioclase constitutes 45 to 55% of the rock with roughly equal amounts of clinopyroxene (15-25%) and orthopyroxene (15-25%). Green hornblende commonly rims both clino- and orthopyroxene in less thoroughly recrystallized samples. Other primary minerals include biotite, apatite, titanite, opaque minerals and quartz. Secondary minerals include actinolite, epidote, white mica, carbonate and chlorite. In many areas, secondary minerals have thoroughly replaced the primary mineralogy.

A variety of textural changes occur within the Nipissing sills with increasing distance into the Grenville Province. Immediately south of the Grenville Front, the Nipissing bodies partially preserve the varitextured appearance common to the sills in the Southern Province. A strong preferred orientation of mafic minerals is developed within the sills near their margins and primary pyroxene is converted to amphibole. Further south, the Nipissing rocks are amphibolites and contain a well-developed planar fabric, which is parallel to compositional layering fabrics in adjacent host rocks. Garnet is rarely developed within any of the Nipissing equivalents in the Grenville Province. Most of the surrounding rock units contain considerable leucosome, however, leucosome rarely occurs in the Nipissing gabbroic rocks within the Grenville Province. The identification of these bodies as metamorphosed Nipissing gabbro sills is based on a combination of outcrop appearance and geochemistry. Both are reliable criteria when the sills exhibit the typical Nipissing chemistry (see "Geochemistry"), however, it is more difficult to separate them from mafic rocks of the East Bull Lake intrusive suite when the sills exhibit the high-magnesium chemistry common to many Nipissing sills in the Southern Province in the Sudbury region (Easton and James 1997b; Easton and Murphy 2002). In hand specimen, rocks of the East Bull Lake intrusive suite typically contain greenish pyroxene grains in addition to black hornblende.

Within the Grenville Province, Nipissing gabbro sills appear to be restricted mainly to a 2 to 3 km wide zone south of the Grenville Front, and are most commonly hosted by rocks of the Front gneiss association. In the Timmins Creek area in Street Township, the Nipissing gabbro sills intrude metasedimentary rocks that are correlated with the Pecors and Mississagi formations (Easton and Murphy 2002). These stratigraphic units overlie or are intruded by Paleoproterozoic age gneissic granite, and consequently, suggest that the Nipissing sills were emplaced near the basal Huronian Supergroup unconformity. This also would explain the general absence of Nipissing sills within the Street and Crerar gneiss associations, since those units consist mainly of rocks that would have represented basement to the Huronian Supergroup in the Paleoproterozoic.

On his map, Lumbers (1973) showed several areas of mafic rock in southwestern Loughrin Township, which he assigned to the Nipissing intrusive suite. Although hosted by gneisses of the Street gneiss association, the mafic rocks in question exhibit many of the textural features typically found within Nipissing intrusive suite rocks within the Grenville Province. Geochemical analysis of one of these bodies (sample 02RME-0152, Appendix 2) suggests chemical affinity with the Nipissing intrusive suite (*see* section immediately following on "Geochemistry").

Intermediate Intrusive Rocks

Fine- to medium-grained, foliated to gneissic quartz diorite, locally exhibiting sub-ophitic texture occurs throughout much of the Front gneiss association in Loughrin Township north and east of Jones Lake. It is associated with gneissic granite of probable Paleoproterozoic age (*see* section on "Felsic Intrusive Rocks"). In the field, these rocks were originally considered as possible Nipissing gabbro sills, however subsequent thin section and geochemical analysis indicated that these rocks were more silica-rich than typical Nipissing sills (*see* section immediately following on "Geochemistry").

Geochemistry

Previous geochemical studies of the Nipissing intrusive suite (Lightfoot and Naldrett 1996) focussed on intrusions in the Cobalt plate of the Southern Province, which are dominated by rocks having moderate MgO contents (7 to 9 wt. %). In the Sudbury area, as noted by Easton and James (1997a, 1997b) and Easton and Murphy (2002), intrusive rocks of the Nipissing intrusive suite are divided roughly equally into 2 types on the basis of MgO content:

1. a moderate MgO group (4 to 8 wt. %, average Mg number of 54 to 59); and
2. a high MgO group (>9 wt. %, average Mg number of 68 to 77). Rocks of the high MgO group are hypersthene normative and correspond to the hypersthene gabbros locally described within Nipissing intrusions present within the Cobalt plate (e.g. Hriskevich 1968; Conrod 1988, 1989; Lightfoot and Naldrett 1996).

On major element plots, such as AFM and Jensen diagrams, the 2 chemical groups show distinct differentiation trends within individual sills. On both the AFM and Jensen diagrams, the moderate MgO group exhibits a typical tholeiitic differentiation trend toward higher iron content with increasing silica (Easton and Murphy 2002). In contrast, the high MgO group exhibits a more moderate iron enrichment trend on an AFM diagram and a trend toward lower MgO and alumina contents on a Jensen diagram (Easton and Murphy 2002).

The 2 groups of Nipissing gabbro bodies also have distinct trace and rare earth element contents (Easton and Murphy 2002). The high MgO group has higher chromium and nickel contents than the moderate MgO group. In addition, the high MgO group has lower total rare earth element abundances and near flat rare earth element patterns at roughly 10 times chondritic abundances. The moderate MgO group exhibits more light rare earth element enrichment, which may reflect more interactions between the parental magma and continental crust prior to sill emplacement.

In terms of economic potential, intrusions of the high MgO group of the Nipissing intrusive suite have higher nickel-copper-platinum group element mineral potential as a result of their more primitive chemical character and their overall higher nickel content. Background levels for gold, chromium, copper, nickel, palladium and platinum from Nipissing intrusions in the study area are provided in Easton and Murphy (2002).

As previously noted by Easton and James (1997a, 1997b) and Easton and Murphy (2002), metamorphosed Nipissing gabbro sills exhibiting typical "Nipissing chemistry" can be reliably distinguished from metagabbronorites of the East Bull Lake intrusive suite within the Grenville Province. This is not the case for the high-magnesium Nipissing sills, which chemically are almost identical to metagabbronorites of the East Bull Lake intrusive suite solely (Easton and Murphy 2002).

A chemical analysis of a possible Nipissing gabbro sill hosted in the Street gneiss association in east-central Loughrin Township (sample 02RME-0152, Appendix 2, Figure 10) has most of the chemical characteristics of moderate-magnesium sills of the Nipissing intrusive suite, although SiO_2 is slightly higher than normal (55.08 wt. % compared to 51.81 wt. % for the average gabbro in Lightfoot and Naldrett 1996).

Foliated to gneissic quartz diorite from the Front gneiss association in the Jones Lake area has a similar rare earth element pattern, although total rare earth element content is higher (192 ppm versus 144 ppm) (sample 02RME-0069, Appendix 2, *see* Figure 10), as is SiO_2 (60.91 wt. %). When the chemistry of the quartz diorite is compared to that of all the major magmatic units within the study area, it most closely resembles that of the Nipissing intrusive suite. Most significantly, it is distinct from that of the

Geon 24 and 23 felsic intrusive rocks that are also found within the Front gneiss association. Lightfoot and Naldrett (1996) describe the presence of quartz diorite differentiates in Nipissing sills in the Lake Temagami area; thus it is plausibe that the quartz diorite represents a feslic differentiate of the Nipissing intrusive suite.

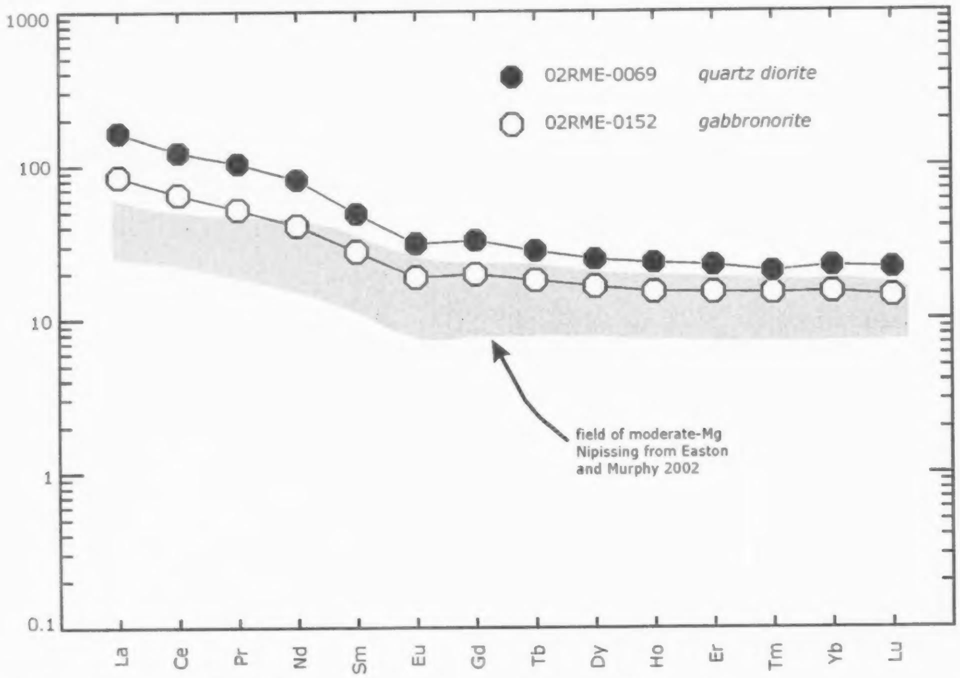


Figure 10. Chondrite-normalized rare earth element plots for Nipissing intrusive suite rocks from Henry and Loughrin townships. Field of moderate-Mg Nipissing intrusive rocks from Easton and Murphy (2002) is shown for comparison.

Mesoproterozoic

SUDBURY DIABASE DIKE SWARM

The Sudbury diabase dike swarm was emplaced into the Southern Province at 1238±4 Ma (Krogh et al. 1987), however, rocks of this swarm are present throughout the northwestern Grenville Province in Ontario (e.g., Ketchum and Davidson 2000; Easton 2002a). Variably preserved segments of diabase dikes are exposed throughout Crerar, Dana, Henry, Loughrin and Street townships, and are assigned on the basis of field appearance and geochemistry (e.g., samples 02RME-0014, 02RME-0255, Appendix 2, Figure 11) to the Sudbury diabase dike swarm (Photos 15 and 16). The larger and better preserved dike segments are located within central Loughrin and western Henry townships within the Street gneiss association and in Dana Township within the River Valley intrusion (*see* Figure 2). The better preserved dikes are relatively unaffected by metamorphism, and in thin section, retain relict olivine grains and show only incipient development of metamorphic coronas around olivine, pyroxene and opaque mineral grains. In contrast, the more recrystallized dike segments, which are located mainly within the area underlain by the Crerar gneiss association, contain little relict primary mineralogy and show extensive metamorphic corona development. In addition to the country rock gneisses, Sudbury swarm diabase dikes have been observed to cut Geon 24 to 23 felsic intrusive rocks, orthopyroxene hornblendite bodies, and rocks of the East Bull Lake intrusive suite in the study area. A Sudbury swarm diabase dike on the boundary road between Henry and Loughrin townships has been examined as a potential building stone (Sawitzky 1994).

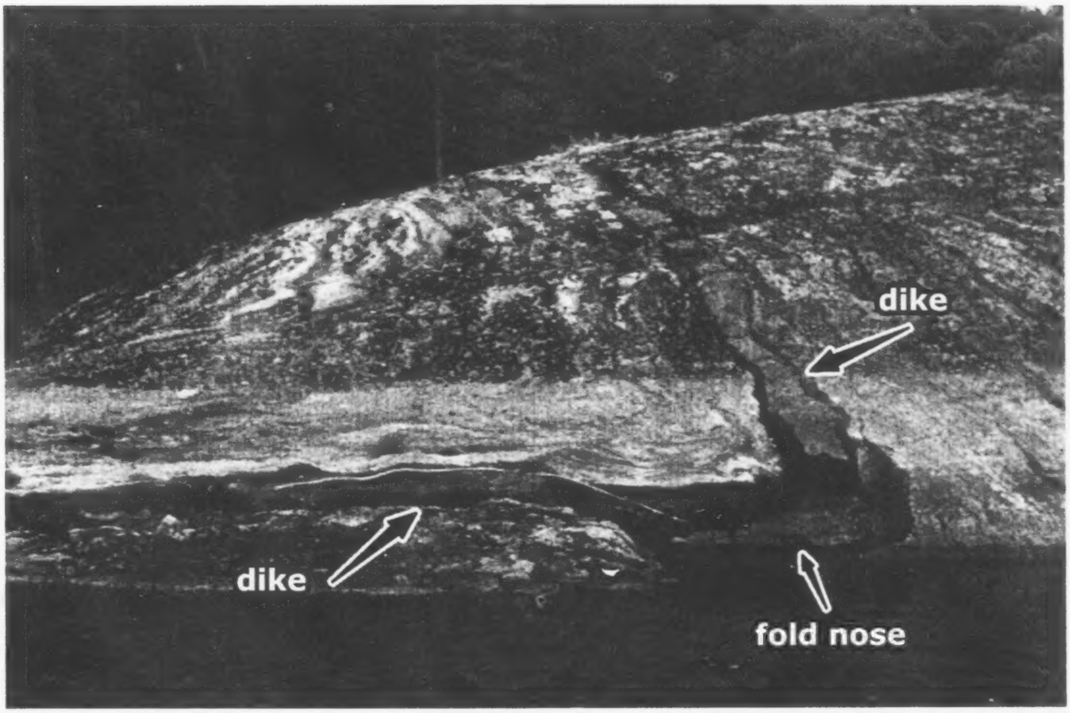


Photo 15. Sudbury swarm diabase dike infolded with rocks of the Pardo gneiss association on Dana Lake. Station 99RME-0237. UTM 556508E 5151840N.

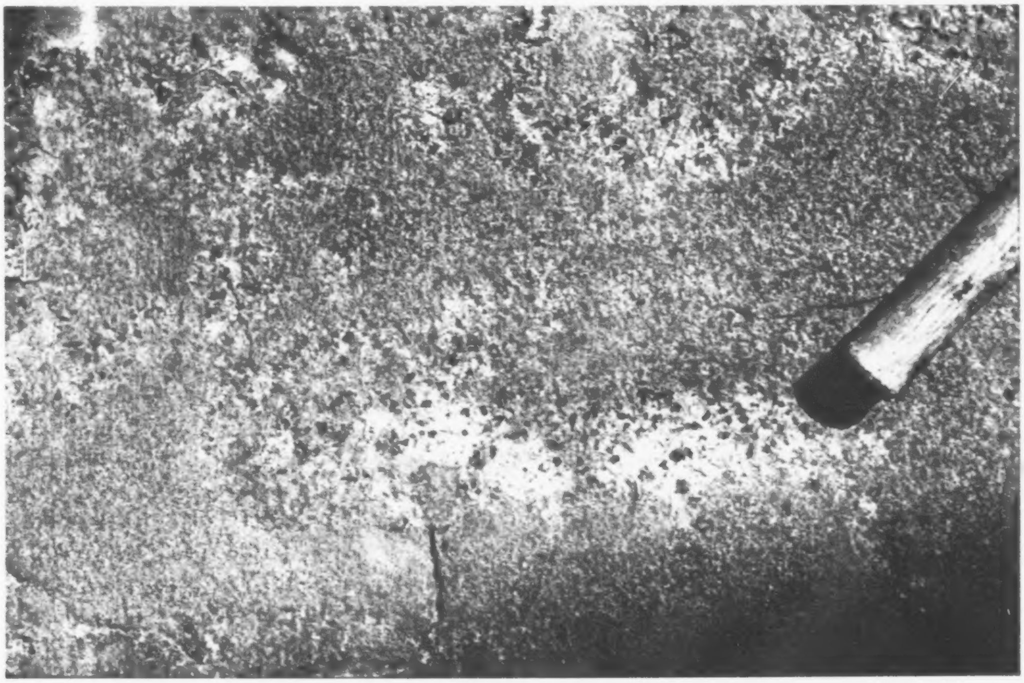


Photo 16. Pegmatitic patches within a large Sudbury swarm diabase dike at a building stone prospecting pit in Loughrin Township, just east of Boundary Road. Hammer handle is 30 cm long. Station 02RME-0016. UTM 544353E 5160492N.

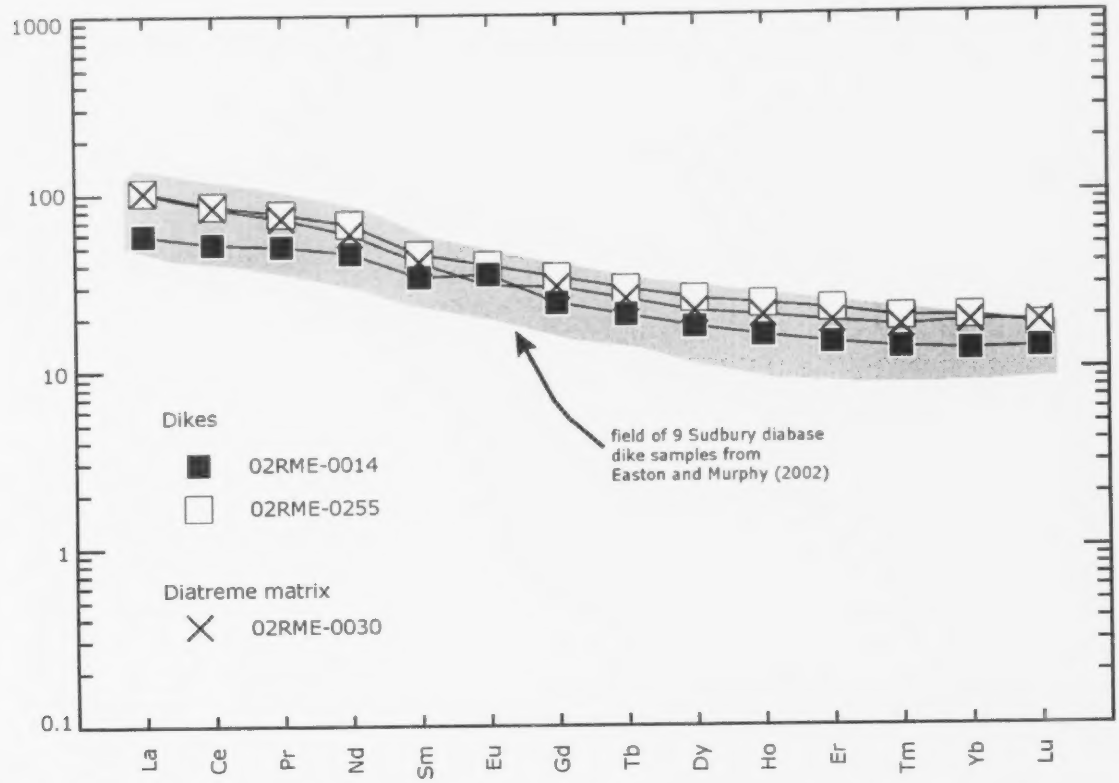


Figure 11. Chondrite-normalized rare earth element plots for Sudbury diabase dike swarm samples from Henry and Loughrin townships. Field of Sudbury diabase dikes from Crerar, Dana and Street townships from Easton and Murphy (2002) is shown for comparison. Also shown is the matrix from the breccia body located in northwest Henry Township.

BRECCIA BODY

Although previously described by Lumbers (1971, 1973), an unusual breccia body located in northwest Henry Township had not been studied in detail prior to this study. It is hosted in recrystallized, foliated to gneissic, mafic intrusive rocks of the East Bull Lake intrusive suite. The breccia body itself consists of angular fragments of apparently unmetamorphosed anorthosite and gabbroic anorthosite, metamorphosed gabbroic anorthosite, quartzite, and felsic intrusive rocks that are hosted in a grey-weathering, fine-grained matrix (Photo 17). Interestingly, it does not contain any fragments that can be clearly linked to the Front, Street or Crerar gneiss associations. In addition, fragments of mafic and ultramafic phases of the East Bull Lake intrusive suite are also rare to absent.

In thin section, the matrix consists of an aggregate of fine-grained quartz, biotite, garnet, plagioclase and amphibole. Garnet is not xenocrystic, but rather is present as a symplectite of fine grains, similar to textures observed in amphibolites of the Street gneiss association. This symplectite texture suggests that the matrix of the breccia body was subjected to the same high-grade metamorphic event and subsequent retrogression effects as the country rocks in the map area. That is, the breccia body is older than 1000 Ma, the age of initiation of closure of U/Pb isotopic systems along the Grenville Front in this area (Corfu and Easton 2000).

A chemical analysis of the matrix of the breccia body (sample 02RME-0030, Appendix 2) indicates that it has the composition of a quartz diorite, and both major and trace element contents indicate that the rock is not alkalic. The contents of some elements, most notably TiO_2, P_2O_5, V, Ba, Nb, Zr, and Y, as well as the rare earth element pattern, are similar to those present in Sudbury swarm diabase dikes (compare samples 02RME-0014 and 02RME-0030, Appendix 2, *see* Figure 11). Thus, it is possible that this breccia may be related to the same magmatic event.

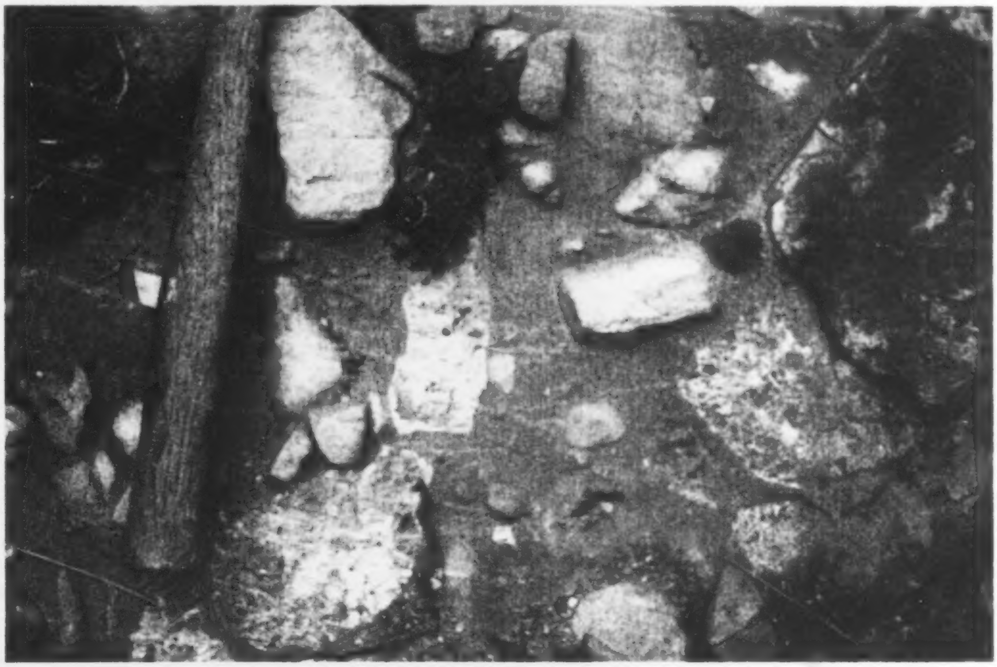


Photo 17. Diatreme-like breccia body located in northwest Henry Township containing angular fragments of unmetamorphosed and metamorphosed River Valley intrusion rocks, as well as quartzite and felsic intrusive rocks. Matrix of the body contains metamorphic garnet, indicating it is older than 1000 Ma. Hammer handle is 30 cm long. Station 02RME-0030. UTM 545031E 5163527N.

Neoproterozoic

GRENVILLE DIABASE DIKE SWARM

An unmetamorphosed diabase dike, present in northern Henry and Loughrin townships, that is associated with a prominent, linear, east-trending, aeromagnetic high, is correlated with the Grenville diabase dike swarm that was emplaced at ~ 590 Ma (Kamo, Krogh and Kumarapeli 1995). The aeromagnetic expression of this dike continues eastward into central Crerar Township, although no outcrops of this dike were observed during the mapping of that township (Easton and Hrominchuk 2001a). Significantly, this dike is offset along its length by north-trending faults, thereby providing a maximum age for these faults within the study area. The mapped width of the dike (~50 m) is about 50% smaller than the geophysical width of the dike. A chemical analysis of this dike is given in Appendix 2 (sample 02RME-0097).

An unmetamorphosed diabase dike in central Dana Township, roughly 5-10 m in width, cuts both country rock gneiss and a Sudbury swarm diabase dike (Photo 18) (Easton and Hrominchuk 2001b).

Based on its geochemical signature, it is also correlated with the Grenville diabase dike swarm (sample 99RME-0138, Appendix 2).

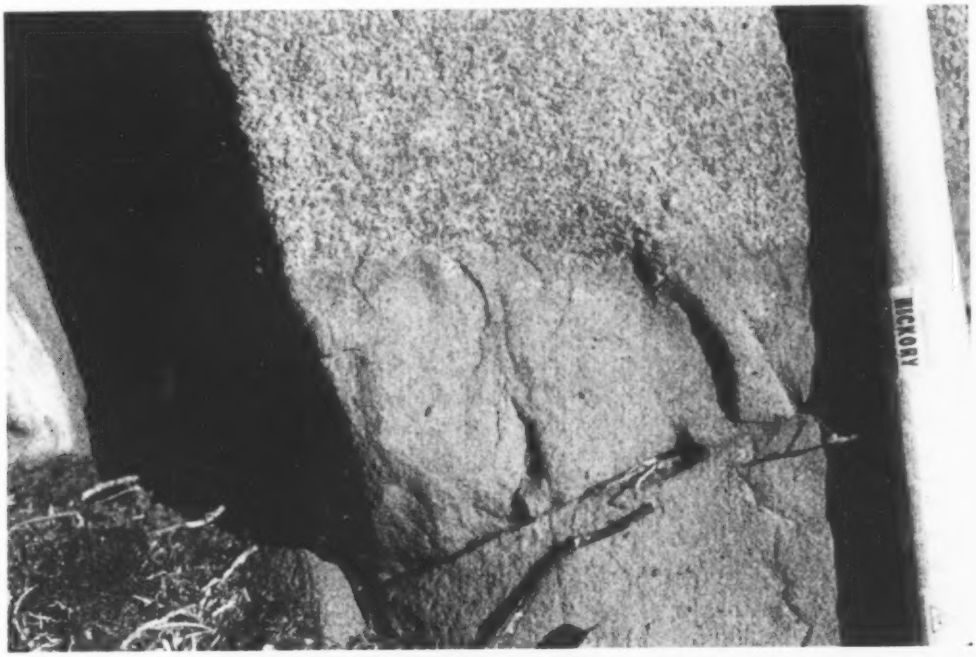


Photo 18. Chilled contact between Grenville swarm diabase dike (bottom) and garnet amphibolite within the Pardo gneiss association, Dana Township. Hammer handle is 30 cm long. Station 99RME-0138. UTM 561225E 5169301N.

REGIONAL METAMORPHISM

Metamorphic grade in the Grenville Province in the study area is upper amphibolite facies. Metamorphic grade is lowest in Street Township, where muscovite is locally present in metasedimentary gneisses. Metamorphic grade increases eastward, as metasedimentary gneisses in northwest Loughrin Township do not contain primary muscovite but are sillimanite-bearing, suggesting metamorphic conditions greater than muscovite-breakdown. Country rocks to the River Valley intrusion and other East Bull Lake intrusive suite bodies, including Proterozoic felsic intrusive rocks in the study area, are commonly migmatitic.

At least 2 regional metamorphic events are preserved within the study area; an earlier Archean event and a younger event associated with the Grenville Orogeny.

Archean rocks in the study area were subjected to a high grade regional metamorphic event, likely at upper amphibolite facies, that resulted in the formation of many of the migmatitic rocks present in the Pardo, Crerar and Street gneiss associations. Migmatization took place prior to ~ 2660 Ma, the age of the megacrystic granodiorite present within the Crerar gneiss association. Based on comparison with other areas, such as the Levack gneiss (*see* Tables 2 and 4), Archean migmatization may have occurred prior to 2660 Ma and at ~ 2645 Ma. There is no unequivocal field evidence from this study, however, that indicates whether there are 1 or 2 Archean migmatization events. There is no thermobarometric data for the Archean metamorphic event, in large part due to overprinting by the Grenvillian metamorphism, however, temperatures were sufficient to cause the widespread development of diatextites.

The Grenvillian metamorphism has affected all rock units in the study area except for the post-metamorphic Grenville swarm diabase dikes. Near the Grenville Front, particularly in rocks of the Front gneiss association, closure of U/Pb isotopic systems in zircon and titanite occurred at ~ 995 Ma (Corfu and Easton 2000). Slightly inboard of the Grenville Front, U/Pb isotopic systems in titanite closed at ~ 980 Ma, at least for rocks of the Pardo and Crerar gneiss associations (S. Kamo, Geochronologist, Jack Satterly Geochronology Laboratory, Royal Ontario Museum, unpublished data, 2003).

Grenvillian metamorphic effects are not uniform across the area. As previously noted, Sudbury diabase swarm dikes within the Front and Street gneiss associations are only partly recrystallized by Grenvillian metamorphism, as are large parts of the River Valley intrusion in Dana Township. Areas least affected by recrystallization are generally distal to faults, contacts, or other discontinuities that may enhance fluid flow during regional metamorphism. Furthermore, some rock types are more resistant to metamorphism, particularly those that contain both orthopyroxene and olivine. Grenvillian metamorphism results in migmatization of some rocks, particularly felsic units. For example, Geon 24 to 23 felsic intrusions in the study area develop leucosomes that have been dated at ~ 995 Ma (Corfu and Easton 2000), however, East Bull Lake and Nipissing intrusive suite rocks rarely develop leucosomes.

Only limited thermobarometric data related to Grenville metamorphism is available for the study area, as summarized in Table 5. These pressure and temperature conditions correspond uniformly to upper amphibolite facies, and correspond to middle crustal levels (~25 km). Both the direct measurements of pressure and temperature by Tettelaar (2000) and the comparison of Sudbury diabase dike metamorphic mineralogy with the study by Bethune and Davidson (1997) in the Killarney area indicate a significant change in pressure and temperature across the Sturgeon River. The area north of the Sturgeon River was affected by pressures and temperatures roughly 2 kbar and 25° to 50°C lower than those observed elsewhere in the study area (*see* Table 5). These lower pressures and temperatures are likely related to the greater degree of preservation of primary igneous mineralogy and textures in the River Valley intrusion north of the Sturgeon River.

In addition to the Archean and Grenvillian metamorphic events, there may be also be a third, Geon 14 metamorphism in the study area. So far, this event has only been recognized isotopically, and then, only proximal to the Grenville Front. Corfu and Easton (2000) report a metamorphic zircon from an orthopyroxene hornblendite body in Street Township that gave an age of 1471±10 Ma. Preliminary data collected from the 2002 geochronology sampling program suggests that a Penokean metamorphism may also be present (~ 1870, based on data from 2 samples; S. Kamo, Geochronologist, Jack Satterly Geochronology Laboratory, Royal Ontario Museum, unpublished data, 2003).

Table 5. Summary of thermobarometric data from the study area. Sudbury diabase dike data is based on comparison of metamorphic mineralogy with that reported by Bethune and Davidson (1997), not direct measurement.

Pressure in kbar	Temperature in °C	Rock Unit	Proximity to Grenville Front	Age of Peak Metamorphism	Source
7.7 to 8.7	700° to 750°	Front gneiss association	0 to 2 km	~995 Ma	Murphy 1999
8.0 to 8.6	700° to 800°	Street gneiss association	5 to 10 km	1040 to 995 Ma	Buckley et al. 1997; Easton and Murphy 2002
5 to 7	625°	River Valley intrusion, Dana Township	10 km	1040 to 1030 Ma	Tettelaar 2000
7 to 9	650°	River Valley intrusion, Crerar Township	10 to 15 km	1040 to 1030 Ma	Tettelaar 2000
6.3 (zone 2/3)	710°	Sudbury diabase, Dana Township	10 km	1040 to 1030 Ma	Bethune and Davidson 1997
8.3 (zone 4)	730°	Sudbury diabase, Crerar Township	10 to 15 km	1040 to 1030 Ma	Bethune and Davidson 1997

REGIONAL STRUCTURE

Regional structure, particularly style and orientation of folding, is difficult to unravel in the study area due to a variety of field-related uncertainties, including: 1) limited outcrop exposure; 2) lack of a reliable stratigraphic framework in East Bull Lake intrusive suite bodies in Henry, Loughrin and Street townships; 3) lack of exposure of contacts between stratigraphic units thereby making it difficult to determine if contacts are structural or stratigraphic; 4) lack of planar fabrics related to large-scale folding; and 5) the interference effects of at least 2 generations of folds.

Folding

As noted by Murphy (1999, 2001), whose study straddled the Grenville Front in the Timmins Creek area, the complexity of structures increases dramatically south of the Ess Creek fault (Grenville Front). Between the Ess Creek fault and the Grenville Front boundary fault of Lumbers (1973), the most prevalent foliation strikes at 060° and dips to the southeast at 70°, parallel to both the Grenville Front boundary fault and the Ess Creek fault. All metavolcanic and metasedimentary rocks within this zone contain tight (F_1) folds with axial planes striking at 050° to 060° and dipping at 60° to 70° southeast. Folding (F_1) is well developed within the garnet-biotite and staurolite-garnet-muscovite ± kyanite schists and is best defined by quartz-feldspar layers or veins within more homogeneous, originally sandy units. Primary bedding is parallel to subparallel to the foliation (S_1) on the limbs of F_1 folds, but they crosscut each other at the nose of the folds.

Banded migmatitic gneisses are present south of the Grenville Front boundary fault of Lumbers (1973). The migmatitic gneisses exhibit tight to isoclinal F_2 folds with axial planes trending 070° and dipping 70° southeast and plunging at 45° southwest. Their attitude is identical to that of F_1 folds immediately to the north of the Grenville Front boundary fault. The migmatites represent the peak metamorphic conditions during F_1 deformation in the Timmins Creek area. F_2 folds do not have an associated S_2 fabric, indicating there was no new growth of metamorphic mineral phases during this second generation of folding. The simplest explanation for this phenomenon is that these F_2 folds formed as a result of the ductile nature of the metamorphic environment attained during the F_1 event. In short, the effects of only one major metamorphic episode are recorded. This is consistent with the geochronology data and cooling history data presented by Easton and Murphy (2002) for the Front gneiss association.

Folding style within the Street gneiss association is characterized by outcrop- and regional-scale refolded folds, generally of type 1 geometry (Ramsey and Huber 1987). Type 2 refolded folds are also present in some areas, most notably affecting the Street metagabbro in southeastern Street Township. Davidson (1998) reports similar fold styles from the Grenville Front tectonic zone immediately southwest of Street Township. In the absence of an established stratigraphic sequence, detailed structural analysis of these folds within the Grenville Province is difficult.

Two structural fabrics dominate the study area south of the Sturgeon River and are oriented roughly perpendicular to each other (Photo 19). Many rock units in the area show an east to east-northeast orientation, however in many places, particularly in western Henry Township, the dominant penetrative fabric in the rock (generally gneissic layering) is oriented in a northerly direction at a high angle to the lithologic contacts. In many East Bull Lake intrusive suite rocks in northern Henry and Loughrin townships, 2 fabrics are observed. In some areas, the easterly fabric is earlier and cut by the northerly fabric, which commonly serves as a focus for local veining or leucosome development. In other areas, the northerly fabric appears to be earlier, and is crenulated by the easterly fabric. It is possible, however, that several generations of fabrics are present, which would explain these apparently contradictory relative age relationships. The lack of a reliable stratigraphy in either the country rock gneisses or the East Bull Lake intrusive suite rocks in the western part of the study area make it difficult to map out large-scale folds, a process further complicated by the fact that rock unit contacts may have different trends than the measured penetrative fabrics within those rock units.

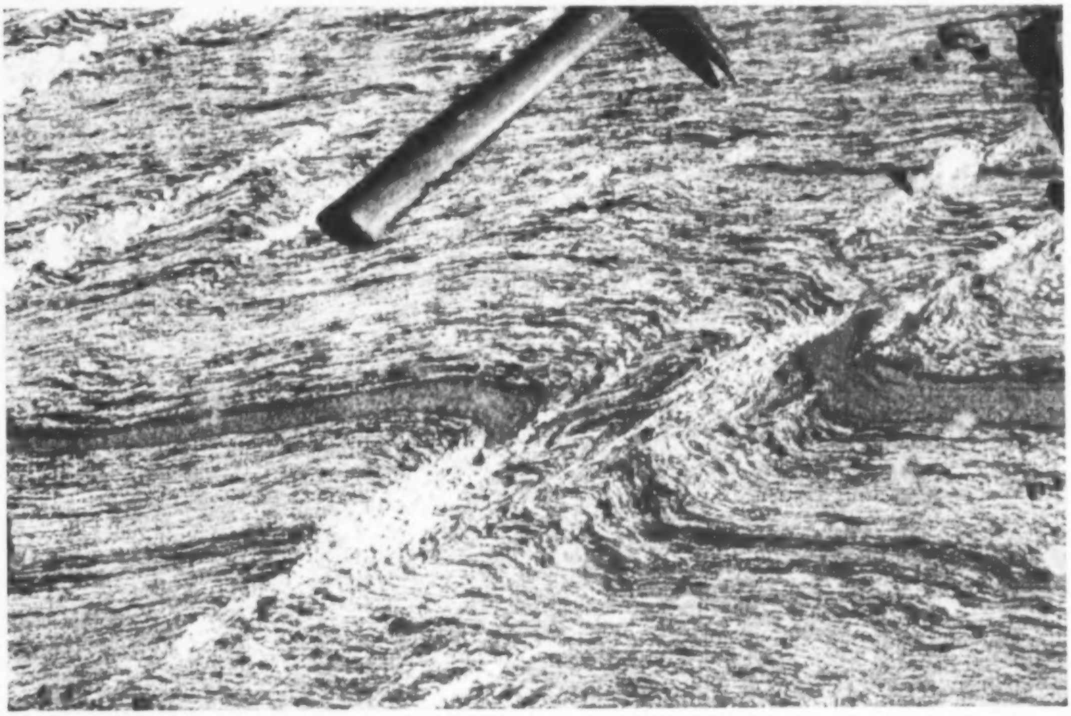


Photo 19. Two generations of fabric in gneissic leucogabbro of the Loughrin Lake intrusion, northwest Loughrin Township. Earlier gneissic layering is kinked and faulted at a high angle. Locally, leucosome collects along the second-generation structure. Hammer handle is 30 cm long. Station 02RME-0051. UTM 534935E 5161451N.

Faulting

There are at least 4 trends of faults within the study area. From youngest to oldest these are:

1. north-trending faults parallel to the Upper Wanapitei River fault (<590 Ma)
2. east-northeast-trending faults subparallel to the Grenville Front north of the Sturgeon River (~990 to 1040 Ma?)
3. east-trending faults that mark the Southern-Grenville province boundary along the Kabikotitwia and Sturgeon Rivers, including the Ess Creek and Grenville Front boundary faults (last movement at ~990 to 1040 Ma?). These faults may represent the trace of the Murray fault system.
4. northeast-trending shear zones south of the Sturgeon River. These include straight gneisses within the Front gneiss association, as well as 2 northeast-trending structures identified by Newman (1996), one of which corresponds to the Street-Crerar gneiss association contact (>1240 Ma?).

The north-trending faults oriented parallel to the Upper Wanapitei River fault are most commonly observed in Henry and Loughrin townships. This may be in part because east-trending units such as the

East Bull Lake intrusive suite rocks and a large Grenville swarm diabase dike provide reliable marker units allowing the indentification of the effects of this north-trending faulting. Similar faults may also be widespread in Crerar and Street townships, but may be more difficult to recognize because of differences in rock units and their orientation.

Newman (1996) suggested the presence of 2 northeast-trending structures in the study area, the northernmost of which he correlated with the Murray fault system. As previously discussed under the section on "Major Fault Systems", it is more likely that the Murray fault system coincides with the Southern-Grenville province boundary. Thick surficial cover makes it difficult to ascertain the character of the northernmost northeast structure identified by Newman (1996). The southern stucture identified by Newman (1996) corresponds closely to the boundary between the Street and Crerar gneiss associations, in part delineated by the Contact intrusion (East Bull lake intrusive suite).

MAGNETIC SUSCEPTIBILITY DATA

Magnetic susceptibility measurements collected by field party personnel from the study area are summarized in Table 6. Readings were collected using an Explorium® KT-9 magnetic susceptibility meter. Magnetic susceptibility is defined as the degree to which a substance can be magnetized, and in this case, is expressed as the ratio of the intensity of magnetization (k) to the ratio of the earth's magnetic field to the magnetic field induced by the susceptibility meter. The readings (k) are expressed as 10^{-3} times the SI unit for susceptibility, and are dimensionless. The minimum value that can be recorded by the meter is 0.01 times 10^{-3} SI units; the largest value is 999 times 10^{-3} SI units.

Strongly recrystallized quartzofeldspathic and mafic gneisses, including tonalite gneiss of the Crerar gneiss association, migmatitic gneiss of the Street gneiss association, and mafic and leucogabbroic gneiss of the East Bull Lake intrusive suite all show relatively low, and consistent, measurements, on the order of 0.1 to 1.2 (*see* Table 6). The homogeneity of these rock types, and their low magnetic character, probably reflects destruction of most primary magnetic minerals in these rocks during regional metamorphism.

Felsic intrusions of Geon 24 and 23 age show a range of measurements between individual outcrops, probably reflecting varied degrees of metamorphic recrystallization (*see* Table 6). Outcrops with minimal leucosome or deformation give high measurements, on the order of 30 to 45, consistent with regional aeromagnetic highs that correspond to areas underlain by these rocks. As leucosome content increases in outcrop, generally near the margins of these intrusions, magnetic susceptibility measurements drop significantly to the 0.4 to 2.0 range. One explanation for this variation is that these rocks once had a more uniformly higher magnetic character, and that the scattered measurements recorded in the field relate to varied degrees of metamorphic recrystallization in these rocks; with completely recrystallized rocks giving low measurements, and partly recrystallized rocks giving higher measurements.

The various units of the East Bull Lake intrusive suite record high measurements in areas where the effects of metamorphic recrystallization and deformation are minimal (*see* Table 6), and low readings (0.4 to 1.0) in areas where the rocks are gneissic. Generally, the orthopyroxene hornblendite bodies give low measurements (<1.0), however, a few bodies do give much higher values (~11 and ~85), possibly reflecting new magnetic mineral growth related to the breakdown of some primary phases such as olivine during regional metamorphism.

Table 6. Summary of magnetic susceptibility characteristics of rock units in the study area.

Map unit	Magnetic susceptibility (range of typical values per outcrop)	Magnetic susceptibility (average values or ranges)	Interpretation
Crerar gneiss association			
Tonalitic gneisses	0.10 to 0.30	0.15	Magnetic minerals destroyed during metamorphism
Street gneiss association			
Quartzofeldspathic migmatites	0.10 to 0.7 and 1.2 to 7 and >10	0.20 to 0.40	Magnetic minerals variably destroyed during metamorphism, low values in areas of complete recrystallization
East Bull Lake intrusive suite			
Mafic gneiss & amphibolite	0.50 to 1.10	0.85	
Leucogabbroic gneiss	0.30 to 0.70	0.45	
Leucogabbro, oxide-bearing gabbro	1.0 to 61	10 to 20	Magnetic minerals variably destroyed during metamorphism, lowest values are in areas of complete recrystallization
Orthopyroxene hornblendite	10 to 99 0.50 to 1.0	11 and 85 0.6	Magnetic minerals created by breakdown of olivine and pyroxene; in outcrops with low values, magnetic minerals were destroyed during metamorphism
Geon 24 and 23 gneissic granites			Magnetic minerals mainly intact
Minimal leucosome	30.0 to 44.5	35.2	Magnetic minerals mainly intact
Leucosome poor	5.2 to 34.5	14.3	Magnetic minerals partly destroyed during metamorphism
Leucosome common	0.4 to 4.4	1.2	Magnetic minerals destroyed during metamorphism
Nipissing metagabbro	0.45 to 1.1	0.65	Magnetic minerals partly destroyed during metamorphism
Sudbury swarm diabase dikes			
Fine-grained, weakly metamorphosed	2.6 to 7.4	4.6	Magnetic minerals mainly intact
Fine-grained, metamorphosed	0.9 to 4.4	1.8	Magnetic minerals partly destroyed during metamorphism
Medium- to coarse-grained	7.9 to 24.3	13.6	Magnetic minerals mainly intact
Pegmatitic patches	54.9 to 88.0	69.3	Magnetic minerals mainly intact
Grenville swarm diabase dikes	22 to 55	38.5	Magnetic minerals unmetamorphosed

Both the Sudbury and Grenville swarm diabase dikes yield moderate to high magnetic susceptibility measurements (*see* Table 6). In general, the Grenville swarm dikes give slightly higher values on a per dike basis. The differences in observed magnetic susceptibility between the Sudbury and Grenville swarm dikes is not sufficient alone to explain the different regional magnetic signature of these dikes. The fact that the Grenville swarm dikes are more prominent may simply reflect their more continuous linear nature, whereas the Sudbury diabase dikes have been tectonically disrupted and are variably metamorphosed, and consequently, individual dike segments are too small to show up in regional magnetic surveys.

REGIONAL GEOPHYSICAL PATTERNS

Integration of magnetic susceptibility measurements in the field, detailed mapping and the airborne geophysical data collected by WMC International Ltd. (Ontario Geological Survey 2002) has resulted in several observations concerning the geophysical characteristics of major rock units within the study area:

1. Recrystallized to gneisssic varieties of East Bull Lake suite mafic intrusive rocks (bodies 1 and 2) generally have low magnetic susceptibilities (<1.0) and appear as magnetic lows on maps of airborne magnetic data.

2. East Bull Lake intrusive suite mafic intrusive rocks of the Contact intrusion are associated with a linear magnetic high, but this high may be the result of neighbouring granitic gneisses, or a structural break associated with the boundary between the Street and Crerar gneiss associations.
3. Small, isolated, ovoid to round magnetic highs up to 500 m in diameter occur in the eastern and western parts of the Loughrin Lake intrusion (East Bull Lake intrusive suite), as noted by Newman (1996). The cause of these anomalies has not yet been determined, but they are not obviously associated with areas of less metamorphic recrystallization or unusual rock types or mineralogy.
4. Felsic intrusive rocks within the Grenville Province are characterized by moderate to high magnetic susceptibility (10-40) and appear as magnetic highs on maps of airborne magnetic data. The magnitude of these highs may be larger than for highs present in areas underlain by preserved rocks of the River Valley intrusion.
5. In general, the mapped contact of East Bull Lake intrusive suite rocks, especially for the Loughrin Lake intrusion, occurs within 200 m or less of the boundaries between areas of magnetic lows (mafic intrusive rocks) and magnetic highs (country rock gneisses or felsic intrusive rocks).
6. The large Grenville swarm diabase dike present south of the Grenville Front in Crerar, Henry and Loughrin townships is characterized by high magnetic susceptibility (35-65), consistent with its expression as a linear magnetic high. The mapped width of this dike is about 50% smaller than the geophysical width of the dike.
7. The Sudbury swarm diabase dikes have low to moderate magnetic susceptibility (3-25), and are of insufficient size or magnetic contrast to be observed in the airborne magnetic data. Similarly, none of the orthopyroxene hornblendite bodies can be clearly observed in the airborne magnetic data. The breccia body present in northwestern Henry Township appears as a small ovoid of moderate magnetic intensity surounded by rocks of more highly magnetic character.
8. Eight aeromagnetic highs (greater than 2500 gammas) are located over the River Valley intrusion. Most are associated with areas of the intrusion that contain partly preserved igneous textures and oxide-rich horizons. The aeromagnetic high located northeast of the Azen Creek zone, is coincident with the Macdonald and Varley mineralized zones identified by Pacific North West Capital Corporation. An aeromagnetic high in the Southern-Grenville province boundary zone, located about 1.5 km southwest of the Dana North mineralized zone, is associated with an area of compass unreliability; however, the cause of this anomaly has not been attributed to any specific geologic unit or feature. The lack of any distinctive aeromagnetic pattern or zonation over the entire River Valley intrusion probably reflects the varied degrees of preservation of the intrusion, with the more intensely deformed and metamorphosed parts of the intrusion showing a different, lower, magnetic susceptibility compared to the parts of the intrusion that contain relict mineralogy and textures. Magnetic surveys may be useful in exploration of the better preserved parts of the intrusion.

MINERAL POTENTIAL OF THE COUNTRY ROCKS

Mineral occurrences in the country rocks in the study area are listed in geological data inventory folios available for Crerar, Dana, Henry, Loughrin and Street townships (Ontario Geological Survey 1985d, 1985a, 1985c, 1985b, 1987, respectively). Exploration activity in the area is summarized in Appendix 1.

In the Southern Province north of the Grenville Front, Nipissing gabbro intrusions have been subjected to extensive exploration for copper-nickel-platinum group element mineralization (Dressler 1979; James et al. 2002b). Such mineralization may be present within the Grenville Province in the study area, but would be restricted mainly to Nipissing gabbro intrusions located in the Front gneiss association.

The high metamorphic grade and quartzofeldspathic composition of most of the country rocks limits their mineral potential. Commodities within the country rock gneisses that have either been explored for, or extracted, in the past include building stone, feldspar, garnet and kyanite.

Building Stone

Several country rock units in northwest Henry Township have been examined as possible building stones, notably Paleoproterozoic granite gneiss (Sawitzky 1994) and Sudbury diabase (Sawitzky 1994). All of these sites are characterized by minimal jointing, sufficient topography, and access to existing roads to make them viable prospects. Building stone prospects or past-producers in rocks of the East Bull Lake intrusive suite are described in the section on "Mineral Exploration" in the second half of this report.

Feldspar

Several extraction pits were developed in large granite pegmatites present in Loughrin Township prior to 1960 (Vos, Smith and Stevenato 1981), the largest of these being present at Jones Lake in northwest Loughrin Township. A sample of feldspar was collected from this locality to test for possible rare metal potential (samples 02RME-0070 and 02RME-0071, Appendix 2). Lithium and cesium were both below detection limits in these samples, K/Ba ratios are less than 550, and Rb is 745 ppm. These elements, along with other key ratios, all indicate that the pegmatites in Loughrin Township fall in the Type 1b (barren) pegmatite type of Gordiyenko (1971) and thus have no rare metal potential. It should be noted that these barren pegmatites are hosted in gneisses of either the Front or Street gneiss association. This does not preclude the possibility of rare metal pegmatites being hosted in the Crerar, Red Cedar Lake or Pardo gneisses located west of the study area, as suggested by Easton (2000).

Garnet and Kyanite

Several discontinuous belts of quartzofeldspathic gneiss and associated garnet-rich gneiss occur between Wahnapitae and River Valley. These belts constitute map unit 18 on the regional reconnaissance geologic map of the River Valley area (Lumbers 1973). These rocks appear to be restricted to a zone located 1 to 5 km southeast and south of the Grenville Front. It is unclear if this distribution reflects an original stratigraphic control, or whether it is the result of tectonism, or some combination of both. In the vicinity of Wahnapitae, kyanite-garnet rich layers are common within this map unit, however, the abundance of kyanite appears to decrease to the northeast; kyanite being only present locally in Street Township, and apparently absent further east. Potential economic garnet prospects have been described in Dryden, Street, Janes and Dana townships.

DRYDEN TOWNSHIP

Kyanite-garnet rocks in the Wahnapitae area were studied in detail by Pearson (1959) and Grant et al. (1962), focussing on their kyanite potential. In many of these kyanite-garnet rocks, garnet is present in amounts of 15-40%, and these rocks need to be re-assessed for their garnet potential. Davidson (1998) has recently re-mapped most of the area studied by Grant et al. (1962), providing greater subdivision of the mafic gneisses present in the area.

STREET TOWNSHIP

The continuation of this garnet-bearing tectonostratigraphic horizon northeast into Street Township is described in greater detail in Easton and Murphy (2002). Where this horizon is being tested by Ecosource Garnet Incorporated, it consists of several thin rock units exhibiting transitional type 1-type 2 interference folds, dominated by a main, possibly late, variably-plunging, northeast-trending synform.

The Ecosource Garnet Incorporated property is accessed from the Kukagami Lake Road, using a 3 km long gravel road that lies subparallel to the Grenville Front and the axial trace of the regional synform noted above. Three separate test quarries are present along the access road; the south zone is located roughly 1.5 km from the Kukagami Lake Road and consists mainly of garnet-rich quartzofeldspathic gneiss. The central zone is located roughly 2.5 km northeast of the Kukagami Lake Road, and in addition to garnet-rich quartzofeldspathic gneiss, also contains the garnet-gedrite rock with golf-ball-size garnets, and kyanite-garnet gneiss. The north zone is located at the end of the road, and consists of garnet-rich quartzofeldspathic gneiss and muscovite-garnet paragneiss. Also in Street Township, golf-ball-size garnets are also present in a 200 m long by 75 m wide zone, just south of Timmins Creek, roughly 1 km northeast of the third quarry.

In 1998, the Ministry of Northern Development and Mines commissioned a test of 5 garnet localities in the northern Grenville Province in Ontario (Grammatikopoulus et al. 1999). Two samples were directly relevant to this study: a sample from Street Township and a sample from Dana Township, likely from the eastward continuation of the same tectonostratigraphic horizon. The Street Township sample was collected from garnet-rich quartzofeldspathic gneiss from the north zone (NTS 41I/10, UTM 530230E, 5159274N) and was representative of the exposed resource. The validity of this sampling rationale is justified if one compares the chemistry of the Street Township head sample, presented in Table 7, with the whole rock geochemistry previously presented in Easton (1996) (*see* Table 7). The head sample and sample 95RME-0137 (north zone), sample 95RME-0136 (central zone), and sample 95RME-0150 (south zone) are all chemically similar. Variation in chemistry is due to minor differences in garnet content. Mineral chemistry data, collected on samples of the garnet-rich quartzofeldspathic gneiss, and the kyanite-garnet and garnet-gedrite rocks (Easton and Murphy 2002), only show minor variations between the different rock types, and the composition of garnets from all these rocks is similar to that reported by Grammatikopoulus et al. (1999) for the Street Township sample.

Grammatikopoulus et al. (1999) provided the following data for the Street Township garnets. Grain size in the head sample ranged from 0.1 mm to 5 cm with a quality index of 5/10 where 0 represents inclusion- and alteration-free grains (excellent quality). More than 95% of the grains in the Street Township sample have inclusions and alteration. Compositional zoning in the Street Township garnets is minimal (<2.5 mole%) with an overall composition of $\mathrm{Alm}_{72.6\text{-}75.1}\mathrm{Prp}_{9.1\text{-}11.5}\mathrm{Grs}_{12.3\text{-}14.4}$. Whole rock chemical data on the head sample is provided in Table 7. Barium content is related to the amount of mica in the sample and is estimated at 10 to 15 volume percent.

Grammatikopoulous et al. (1999) also tested garnet recovery following an iterative cycle of crushing and magnetic separation. Results showed that although garnet recoveries were generally very high, the concentrate grades were generally poor. Grammatikopoulus et al. (1999) attributed this to the following factors: 1) the degree of liberation was insufficient particularly at the coarser sizes; 2) overlapping magnetic susceptibilities of garnet and gangue components reduced the effectiveness of magnetic separation; 3) the high proportion of deleterious gangue impeded efficient magnetic separation; and 4) the absence of a suitable pre-concentration stage to eliminate lighter silicates. A test using heavy liquid separation, prior to magnetic separation, improved concentrate grade with no loss in recovery.

Table 7. Chemistry of garnet-bearing felsic gneisses from Street and Dana townships.

Sample No.	95RME-0136	95RME-0137	Head sample, Street Twp.	95RME-0150	Head sample, Dana Twp.
Easting	530160	530262	530263	525010	563080
Northing	5158586	5159281	5159281	5152024	5168450
wt. %					
SiO_2	56.26	51.73	56.10	51.80	52.90
TiO_2	1.01	0.96	0.92	1.38	0.78
Al_2O_3	16.77	17.53	14.30	19.06	16.70
Fe_2O_3	16.10	23.86	22.10	21.31	19.80
MnO	0.21	0.30	0.26	0.20	0.16
MgO	3.11	1.31	2.61	1.79	5.89
CaO	2.28	2.18	2.75	0.98	1.13
Na_2O	2.58	0.03	0.25	0.13	0.98
K_2O	1.37	1.82	1.91	2.26	2.25
P_2O_5	0.18	0.04	0.16	0.10	0.25
CO_2	0.09	0.15		0.09	
S	0.08	1.09		0.16	
LOI	0.01	0.02	0.59	0.22	0.22
Total	99.16	99.68	101.95	97.85	101.06
CIA	73.2	81.9	74.4	85.3	79.3
Mg #	27.7	9.8	19.0	14.3	37.1
ppm					
Cr	145	186	300	99	300
Ni	66	97		67	
Co	44	57		49	
Sc	27	28		33	
V	196	188	400	305	200
Cu	114	228		79	
Zn	110	96		67	
Rb	54	64	96	69	42
Ba	809	894	420	1595	451
Sr	56	12	11	12	57
Nb	12	9	8	21	13
Zr	216	183	169	467	208
Y	49	53	35	112	18
Zr/Y	4.4	3.5	4.8	4.2	11.6

Samples 96RME-0136, 96RME-0137 and 96RME-0150 from Easton (1996) and Easton and Murphy (2002); head samples from Dana and Streeet townships from Grammatikopoulus et al. (1999).

LOUGHRIN TOWNSHIP

Two garnet-kyanite occurrences are located in western Loughrin Township. One occurrence, previously described by Easton and Murphy (2002), occurs as a large enclave of kyanite-garnet-biotite gneisses hosted in mafic gneiss of the River Valley intrusion near the Street Township boundary (UTM Zone 17, 533430E, 5158825N). It contains almandine garnet ranging in size from 15 to 50 mm and pale-blue kyanite laths up to 20 mm long. The second occurrence is located on the north shore of Simpson Lake (UTM Zone 17, 533975E, 5162471N), and is hosted in a package of metasedimentary gneisses similar to those that host the Ecosource garnet occurrences in Street Township (Easton and Murphy 2002), and likely represents the northeast continuation of this zone. Although the Simpson Lake occurrence contains golf- to tennis-ball-size garnets, the garnets are inclusion-rich and consist of aggregates of small garnet grains. Kyanite at the Simpson Lake occurrence, although locally abundant (up to 30% of the rock), is grey to dark grey in colour. Thus, both garnet and kyanite at this occurrence are of poorer quality than at the Ecosource Garnet property.

JANES TOWNSHIP

Dressler (1979) reported garnet-rich rocks in southwestern Janes Township, southeast of Chudleigh, as well as golf-ball-size garnets just south of the Kabikotitwia River. Both these occurrences are broadly similar in lithology, and probably represent the eastward continuation of the garnet-bearing tectonostratigraphic horizon.

DANA TOWNSHIP

The history of the Dana garnet occurrence is outlined in Vos, Smith and Stevenato (1981). In brief, Niagara Garnet Company acquired the property during the 1920s and shipped some 800 tons of ore during the late 1940s until the property was taken over by Industrial Garnet Company in 1956. The federal Department of Mines and Technical Surveys subsequently prepared a report on the deposit and the separation techniques that were used (Ross 1959). Further development work on the property, consisting of stripping, detailed mapping, and local trenching, occurred in 1969 and in 1997-98 (*see* Appendix 1).

The Dana Township occurrence lies roughly 500 m north of the northeast margin of the River Valley intrusion, and is located roughly 5 km north of the village of River Valley. A dirt track leads from Highway 805 to the occurrence. The gneissic rocks that host the occurrence appear to be a large enclave that is engulfed within at least 2 separate alkali feldspar granite intrusions. These intrusions are likely 2640 million years old, based on U/Pb dating in the area conducted as part of this study (S. Kamo, Geochronologist, Jack Satterly Geochronology Laboratory, Royal Ontario Museum, unpublished data, 2003). To the north and east, the alkali feldspar granite intrusions cut gneisses of the Neoarchean Pardo gneiss association, however, the gneissic rocks at the Dana Township garnet occurrence (Photo 20) are similar to the garnetiferous horizon described above in Street and Janes townships (i.e., they are part of the Street gneiss association).

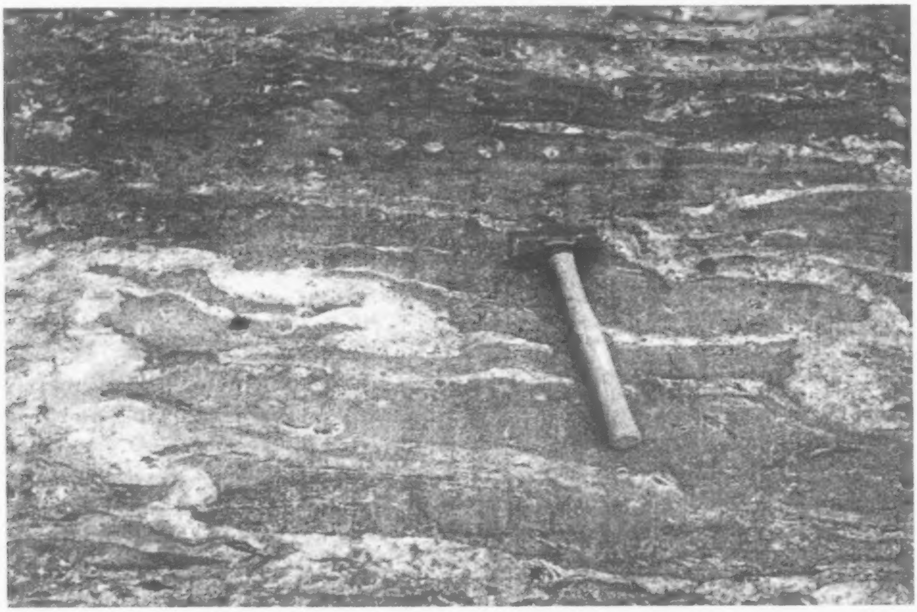


Photo 20. Garnetiferous gneisses at the Dana garnet occurrence, Dana Township. Hammer handle is 40 cm long. Station 99RME-0131. UTM 563200E 5168265N.

The Dana Township garnet occurrence gneisses, however, cannot be directly linked to the garnet-bearing tectonostratigraphic horizon because of the intervening River Valley intrusion, and the fact that they are surrounded by granite. The geochemistry presented herein (*see* Table 7) is certainly consistent with the view that the Dana Township garnet occurrence may be part of the same horizon (i.e., Street gneiss association). If so, then this occurrence represents an outlier of Street gneiss association rocks, possibly only preserved because it was engulfed by the granite intrusions. Anorthositic dikes, now deformed, cut the gneisses associated with the garnet-rich horizons, suggesting that the protolith is older than the anorthosite.

The occurrence lies on the south-facing slope of an east-trending ridge consisting of migmatitic gneiss and granitic gneiss. The sample reported in Table 7 was collected on the southwest side of the ridge, from an area of blasted rock within the unit (NTS 41I/9, UTM zone 17, 563080E, 5168450N). This site was chosen largely because of the availability of relatively fresh, representative material. In hand-sample, the rock resembles the garnet-gedrite rock present at the Street Township site, although in Dana Township, biotite, not orthoamphibole, is the dominant mafic mineral. Biotite is reported also as the dominant mafic mineral at the Janes Township golf-ball-size garnet locality. Roughly 250 m to the east, along strike, several old trenches, and a water-filled adit, all surrounded by garnet-rich rubble, are present, again on the south-facing flank of the ridge. The extent of the garnet-rich zone to the east and the west is unknown due to the presence of overburden.

Grammatikopoulus et al. (1999) provided the following data for the Dana Township garnets. Grain size in the head sample ranged from 0.2 mm to 1 cm with a quality index of 3/10 where 0 represents inclusion- and alteration-free grains (excellent quality). More than 95% of the garnet grains in the Dana Township sample have inclusions and alteration. Compositional zoning in the Street Township garnets is minimal (<4 mole%) with an overall composition of $Alm_{69.1-76.3}Prp_{17.5-25.7}Grs_{2.2-6.2}$. Whole rock chemical data on the head sample is provided in Table 7. Barium content is related to the amount of mica in the sample and is estimated at 10 to 15 volume percent. Grammatikopoulus et al. (1999) also tested garnet recovery following an iterative cycle of crushing and magnetic separation. Results showed that although garnet recoveries were generally very high, the concentrate grades were generally poor. Overall, the results for the Dana Township sample were similar to those for the Street Township sample.

PROTOLITH

A brief comment is warranted with respect to the possible protolith of these two samples, as this topic has implications for exploration for additional resources. Lumbers (1973) regarded his unit 18 as being wholly of metasedimentary origin, and it is certainly true that the garnet-rich rocks are associated locally with rocks with high quartz contents. The latter is most easily regarded as being derived from quartz arenites. The chemistry of the Street and Dana township samples reported herein, however, have low Al_2O_3, Na_2O, and Sr contents, and high Fe_2O_3 contents; all features atypical of pelitic rocks (*see* Table 7, also Easton and Murphy 2002). In the case of the Street Township rocks, this unusual chemistry led Easton (1996) to speculate that the garnet-rich quartzofeldspathic gneisses were derived from hydrothermally-altered felsic and intermediate volcanics interlayered with a few sedimentary horizons; whereas the associated garnet amphibolites were derived from mafic volcanic or volcaniclastic rocks. Subsequent regional metamorphism associated with the Grenville orogeny led to the development of the large garnet porphyroblasts now present in these rocks. If this is indeed the case, then one might expect the resultant original alteration pattern to have been irregular, and of varied intensity. This may explain why the garnet-rich zones are present as discontinuous zones, of varied mineralogy, rather than being more homogeneous in composition. This, combined with structural transposition and fold repetition, may be why this zone is present only in a narrow zone near the Grenville Front, yet can be traced almost 50 km along regional strike.

OTHER GARNET OCCURRENCES

Locally, horizons ranging from 50 cm to 5 m thick containing between 15% to 30% garnet occur within the Street gneiss association, particularly in western Loughrin Township. These occurrences are not directly related to the discontinous belts of associated large garnet occurrences described above. Known occurrences in Loughrin Township include the MacDonald and Page occurrences, both described by Vos, Smith and Stevenato (1981). The Page occurrence is considerably overgrown, and it is difficult to assess the potential of this occurrence, however, the host gneiss at this occurrence is not a particularly favourable host for significant garnet mineralization, based on the author's familiarity with known garnet occurrences in adjacent Street Township (Easton and Murphy 2002).

East Bull Lake Intrusive Suite

REGIONAL GEOLOGICAL SETTING

The Paleoproterozoic East Bull Lake intrusive suite (Easton 1999a; James et al. 2002a) consists of several bodies of dominantly gabbronorite to gabbroic anorthosite composition that occur in both the Southern and Grenville provinces between Elliot Lake and the Ottawa River (*see* Figures 1, 12). The three largest bodies are the River Valley intrusion (Grenville Province) and the East Bull Lake and Agnew Lake intrusions (Southern Province) (Appendix 4). All were emplaced between ~2491 and 2475 Ma (Table 8). Smaller bodies include the Drury, Falconbridge, May, Street and Wisner townships intrusions (*see* Appendix 4, Figure 12).

Most East Bull Lake intrusive suite bodies were emplaced into Archean-age rocks present in either the Superior or Grenville provinces. Table 2 summarizes the main geological events that have occurred in this part of the Canadian Shield during the Precambrian. The distribution of East Bull Lake intrusive suite bodies approximates the base of the Huronian Supergroup in the Southern Province (*see* Figure 12). Contact relationships between rocks of the East Bull Lake intrusive suite and the Huronian Supergroup are either faulted or equivocal. Consequently, it is not known for certain if the East Bull Lake intrusive suite intruded the Huronian Supergroup, or was unconformably overlain by it, or both (e.g., Card 1978; McCrank et al. 1989; Peck, James and Chubb 1993).

Emplacement of the East Bull Lake intrusive suite bodies, subsequent eruption of volcanic rocks of the Huronian Supergroup, and formation of the depositional basin later filled by Huronian Supergroup sediments is attributed by most authors (e.g., Card et al. 1972; Young 1983; Fahrig 1987; Hoffman 1989; Bennett, Dressler and Robertson 1991; Heaman 1997; Card and Poulsen 2000; Ernst and Buchan 2001) to be an intracontinental rifting event resulting from a mantle-plume centered near Sudbury. A suite of igneous rocks (hereafter called the "rifting suite") records the initial trace of this plume-induced rifting event; from oldest to youngest, they include:

1. the East Bull Lake intrusive suite (~2490-2470 Ma)
2. Elliot Lake Group volcanic and minor plutonic rocks, for example, the Elsie Mountain, Stobie and Copper Cliff formations, May Township volcanic rocks, and minor syn-volcanic mafic intrusions (~2490 to 2450 Ma). Volcanic rocks of the Elliot Lake Group constitute the lowermost of four stratigraphic groups in the Huronian Supergroup.
3. Matachewan (2473 Ma) and Hearst (2446 Ma) mafic dike swarms (Heaman 1997).

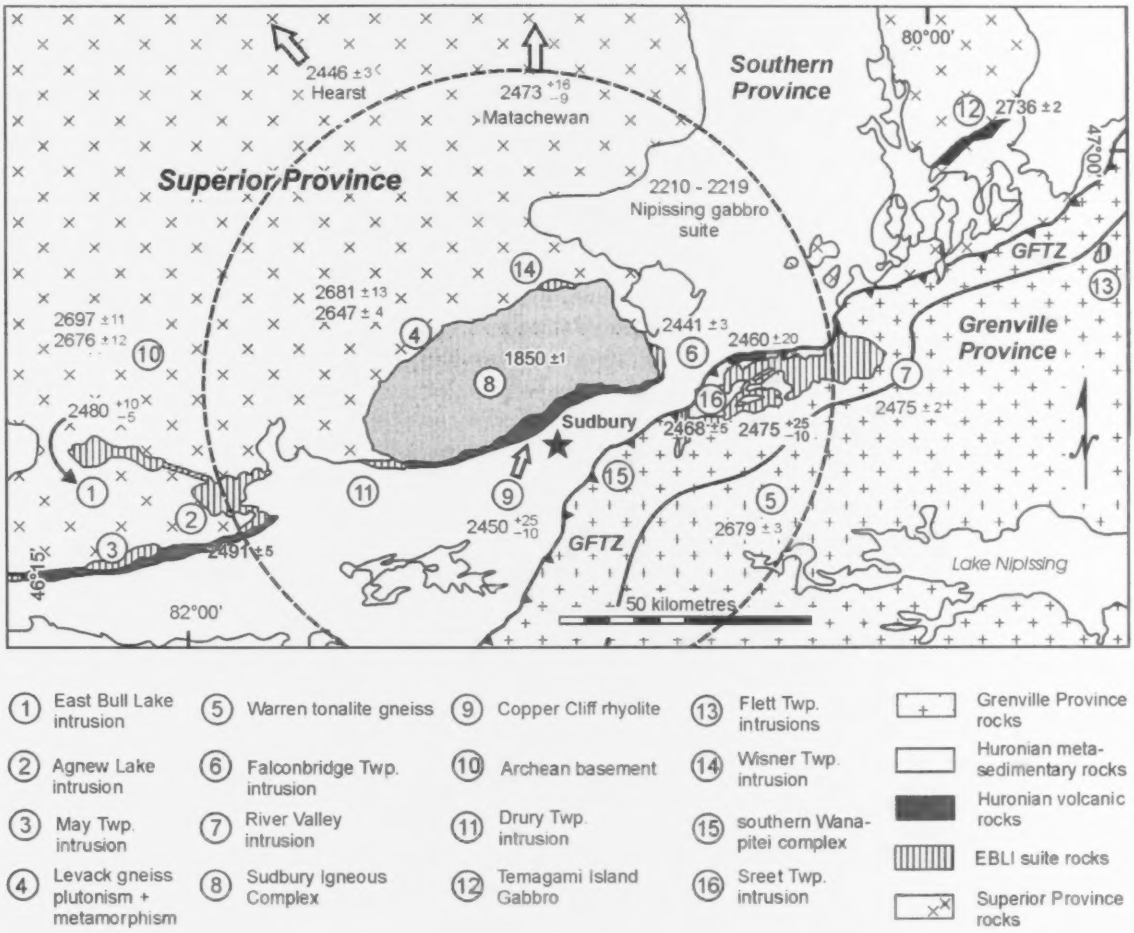

2446 ±3
Hearst
2473 +16 −9
Matachewan
Southern Province
80°00'
2736 ±2
47°00'
Superior Province
2210 - 2219
Nipissing gabbro suite
GFTZ
Grenville Province
2681 ±13
2647 ±4
2697 ±11
2676 ±12
2441 ±3
2460 ±20
1850 ±1
Sudbury
2480 +10 −5
2468 ±5
2475 +25 −10
2475 ±2
2450 +25 −10
2679 ±3
2491 ±5
46°15'
82°00'
GFTZ
Lake Nipissing
50 kilometres
1 East Bull Lake intrusion
2 Agnew Lake intrusion
3 May Twp. intrusion
4 Levack gneiss plutonism + metamorphism
5 Warren tonalite gneiss
6 Falconbridge Twp. intrusion
7 River Valley intrusion
8 Sudbury Igneous Complex
9 Copper Cliff rhyolite
10 Archean basement
11 Drury Twp. intrusion
12 Temagami Island Gabbro
13 Flett Twp. intrusions
14 Wisner Twp. intrusion
15 southern Wanapitei complex
16 Sreet Twp. intrusion
Grenville Province rocks
Huronian metasedimentary rocks
Huronian volcanic rocks
EBLI suite rocks
Superior Province rocks

Figure 12. Distribution of U-Pb zircon ages from Neoarchean and Paleoproterozoic rocks in the Sudbury area, as well as the distribution of East Bull Lake intrusive suite (EBLI) bodies. Dashed circle indicates 125 km radius from a point central to the Sudbury Structure; most intrusions lie within this radius. Sources used: 1, 2, 8, 9) Krogh, Davis and Corfu 1984; 4) Wodicka & Card 1995; Krogh, Davis and Corfu 1984; 5) Chen, Krogh and Lumbers 1995; 6 & 10) Prevec 1993; 7) Heaman in Easton, Davidson and Murphy 1999; below and above circle 16, Corfu and Easton (2000). Age of Hearst and Matachewan dikes from Heaman (1997).

4. Granitic intrusions within the Elliot Lake Group and the Superior Province (~2450 to 2460 Ma), including the Creighton and Murray plutons and the Street Township granitic plutons that may be coeval with Elliot Lake Group felsic volcanism.

Current geochronological data suggests 2 main pulses in magmatism.

1. a predominantly mafic pulse at ~2475 Ma, represented by the East Bull Lake intrusive suite, the Matachewan dikes, and the mafic part of the Elliot Lake Group; and
2. a felsic-dominated pulse at ~2450 Ma, represented by felsic volcanic rocks of the Elliot Lake Group, related granitic intrusions, and the Hearst dikes.

The rifting event produced an east-trending, southward-deepening basin that likely resulted in formation of oceanic crust (e.g., Card et al. 1972; Young 1983; Fahrig 1987; Hoffman 1989; Bennett, Dressler and Robertson 1991). The geometry of the Matachewan and Hearst dikes and their distribution with respect to the metavolcanic rocks of the Elliot Lake Group is consistent with the north-northwest trend of the dikes reflecting the orientation of a failed arm of the rift (e.g., Fahrig 1987; Ernst and Buchan 2001). If this geometry is correct, then the east-trending East Bull Lake intrusive suite bodies not only occur along the continent-side of the resultant rift basin, but also within a 125 km radius of a plume centered on Sudbury (*see* Figure 12). At present, it is uncertain if the East Bull Lake intrusive suite rocks occur directly along a cryptic structure, or structures, related to this rift basin, or if the present distribution of the bodies reflects some other emplacement mechanism (James et al. 2002a).

Within the Southern Province, rocks of the East Bull Lake intrusive suite are affected by folding and upper greenschist to lower amphibolite facies metamorphism associated with the Penokean orogeny, likely around 1835 Ma (Holm et al. 2001; *see* also Tables 2 and 6). Within the Grenville Province, rocks of the East Bull Lake intrusive suite may have been locally affected by metamorphism and deformation at ~1700 Ma and ~1450 Ma, in addition to the main pulse of Grenville orogenesis at ~1070 to 1040 Ma (Corfu and Easton 2000).

Table 8. Summary of geochronology on rocks of the East Bull Lake intrusive suite.

Intrusion	Age (in Ma)	Method	Reference	Comment
Absolute Ages				
Agnew Lake	2491±5	U/Pb zircon	Krogh, Davis and Corfu (1984)	age from alkali feldspar granite which may not be part of the intrusion.
East Bull Lake	$2480^{+10}/_{-5}$	U/Pb baddeleyite and zircon	Krogh, Davis and Corfu (1984)	from olvine gabbronorite zone, few grains results in high error.
	2472±76	Nd/Sm whole-rock and mineral	McCrank et al. (1989)	from olivine gabbronorite zone.
	1859±5	Ar/Ar hornblende	Kamineni (1986)	no details on location.
	1725±18	K/Ar whole-rock	McCrank et al. (1989)	from olivine gabbronorite zone.
	1155±14	K/Ar whole-rock	McCrank et al. (1989)	from olivine gabbronorite zone.
Drury Twp.	1855±10	U/Pb zircon	Prevec (1993)	shocked zircons, dates Sudbury event.
Falconbridge Twp.	2441±3	U/Pb zircon	Prevec (1993)	
	~1850	U/Pb zircon	Prevec (1993)	lower intercept, dates Sudbury event.
River Valley	$2475^{+2}/_{-1}$	U/Pb baddeleyite and zircon	Heaman, unpublished in Easton, Davidson and Murphy (1999)	from layered gabbronorite zone, either in Erana or Dana quarry, north of Sturgeon River.
	2562±165	Pb/Pb whole-rock	Ashwal & Wooden (1989)	n=6, igneous textured samples only.
	2377±68 2165±130	Nd/Sm whole-rock and mineral	Ashwal & Wooden (1989)	n=4, igneous textured samples only, second age is resetting event.
	2185±105, 1960±100	Rb/Sr whole-rock	Ashwal & Wooden (1989)	n=4, second age is resetting event.
Street Twp.	2468±5	U/Pb zircon	Corfu & Easton (2000)	age from orthopyroxene hornblendite body thought to be genetically related to East Bull Lake intrusive suite.
Relative Ages				
River Valley	>2446±3	U/Pb baddeleyite and zircon	Heaman (1997), Easton & Hrominchuk (1999)	River Valley intrusion is cut by dikes of the Matachewan dike swarm.
	>2460±20, $2475^{+25}/_{-10}$	U/Pb zircon	Corfu & Easton (2000), Easton & Hrominchuk (1999)	River Valley intrusion is cut by felsic dikes likely related to felsic intrusions coeval with Huronian Stobie Formation.
Street Twp.	$>2475^{+25}/_{-10}$	U/Pb zircon	Corfu & Easton (2000), Easton & Murphy (2002)	Gneissic granite of this age contains rafts of gabbroic anorthosite and gabbronorite from adjacent intrusion.

OVERVIEW OF EAST BULL LAKE INTRUSIVE SUITE

Appendix 4 lists all known major members of the East Bull Lake intrusive suite along with notable features common to all and a listing of all studies performed to date. The distribution of the major members of the East Bull Lake intrusive suite is illustrated in Figures 2 and 12. Table 8 summarizes the geochronology of the suite. The 3 largest intrusions are the East Bull Lake, Agnew Lake, and River Valley intrusions, all of which have been mapped in the last decade at either 1:10 000 or 1:20 000 scale in whole or in part (Chubb 1994; Peck et al. 1995; Vogel 1996; Easton and Hrominchuk 2001a, 2001b), with accompanying petrological, geochemical or economic studies (James and Born 1985; McCrank et al. 1989; Chubb 1994; Peck, James and Chubb 1993; Peck et al. 1995; Vogel 1996; Vogel, James and Keays 1998; Vogel et al. 1998, 1999; Easton and Hrominchuk 1999; Hrominchuk 1999, 2000; James et al. 2002a, 2002b).

The preserved size of the intrusions varies from 1 to ~100 km^2 (Appendix 4). The most completely preserved body is the Agnew Lake intrusion with approximately 2 km of stratigraphic section; both the East Bull Lake intrusion and River Valley intrusion contain roughly 1 km of section. The East Bull Lake, Agnew Lake and River Valley intrusions are sporadically layered at centimetre- to decametre-scale throughout their stratigraphy.

Leucogabbronorite and gabbronorite are the dominant rock types in the lower and middle parts of most East Bull Lake intrusive suite bodies. Olivine gabbronorites are present in both the East Bull Lake intrusion and the Agnew Lake intrusion, and melagabbronorites and troctolites are common in the lower parts of the River Valley intrusion. Ferrogabbros, ferrosyenites and alkali granites form the top 150 m of the Agnew Lake intrusion. The signficant volume of melanocratic norites and troctolites recognized in the River Valley intrusion is not present in those intrusions west of the Grenville Front, and may indicate that the former represent a deeper part of the stratigraphy of this intrusive suite. The crystallization order of primocryst phases in most of the intrusions is plagioclase, olivine, orthopyroxene, clinopyroxene and titanomagnetite. The attitude of metre-scale phase layering and stratigraphic units in the East Bull Lake intrusion and the Agnew Lake intrusion suggest that they represent lopoliths joined by dike-like units (James et al. 2002a). Original geometry of the bodies present in the Grenville Province cannot be reliably ascertained, although the northeast part of the River Valley intrusion appears to consist of a shallowly dipping (10° to 30°) sheet.

Without exception, breccias containing footwall and mafic cognate xenoliths in a gabbronorite matrix occur at the base of all intrusions, where the footwall contact is preserved. The thickness and abundance of these breccia units varies considerably. Also near the contact, footwall breccias and zones of extensive footwall dikes may be present. Disseminated chalcopyrite and pyrrhotite, typically in modal amounts from 0.5 to 2.0%, occur in the matrix of the marginal and brecciated rocks. This sulphide mineralization commonly contains between 1 and 5 g/tonne of combined Pt+Pd +Au, and is the basis for current mineral exploration in the East Bull Lake intrusive suite (James et al. 2002a, 2002b).

NOMENCLATURE

The term East Bull Lake intrusive suite was only recently introduced by Easton (1999a), and is similar to the term, East Bull Lake suite, used by Vogel et al. (1999). Prior to 1991, rocks of this suite were generally only described as individual intrusions, or as gabbro-anorthosite bodies that were intrusive into the lower part of the Elliot Lake Group (e.g., Bennett, Dressler and Robertson 1991). Prevec et al. (1995) referred to rocks of the East Bull Lake intrusive suite as "trans-Huronian" intrusions. Other authors

(Keays et al. 1995; Peck et al. 1995) grouped them as part of the Huronian-Nipissing Magmatic Province, Domain, or Belt, terms no longer commonly used.

Nomenclature of individual intrusions within the East Bull Lake intrusive suite has been inconsistent over the years, however, James et al. (2002a) attempted to standardize the nomenclature for the intrusions within the suite, and to make this terminology consistent with the North American Stratigraphic Code (NACSN 1983). For example, the intrusion located west of Agnew Lake has been termed the Shakespeare-Dunlop intrusion, the Shakespeare-Dunlop gabbro-anorthosite intrusion, the Agnew Lake Intrusion and the Agnew intrusion, which was standardized in James et al. (2002a) as the Agnew Lake intrusion. The standardization of nomenclature recommended by James et al. (2002a) is used herein, and is summarized in Appendix 4. Appendix 4 also includes the location of reference sections for the better studied intrusions, details on contact relationships, and brief descriptions of the various intrusions.

Recent studies on the East Bull Lake intrusive suite have used a three-tiered classification scheme to describe the rocks of the suite (e.g., Chubb 1994; Vogel 1996; James et al. 2002a), and this approach is retained herein. The first-tier differentiates rock types based on colour index and variation in modal abundance of mafic minerals and plagioclase. The second-tier groups individual rock layers into mappable series, zones, subzones and units (Irvine 1982). It should be noted that units outlined by this second-tier classification are not formal stratigraphic units as defined by the North American Stratigraphic Code (NACSN 1983), although some units, in particular the zones, are roughly equivalent to lithodemic units. The third-tier is based on petrography or distinctive textures, but also uses the IUGS classification scheme for plutonic rocks (Le Maitre 1989) where primary mineralogy or whole-rock geochemistry is present. Most igneous mafic minerals are replaced by amphibole, chlorite and epidote group minerals, reflecting regional metamorphism, in East Bull Lake intrusive suite bodies in the Southern Province. Plagioclase may be unaltered or partially to completely saussuritized. East Bull Lake intrusive suite rocks within the Grenville Province can range from almost wholly unaltered to completely recrystallized to an upper amphibolite facies, amphibole-plagioclase assemblage (e.g., Easton and Hrominchuk 1999; Tettelaar 2000; Easton 2002b). In either geological province where metamorphic alteration is pervasive, rock nomenclature is based on geochemically determined CIPW-normative mineralogy combined with petrographic data.

DEPTH AND MECHANISM OF EMPLACEMENT

Researchers studying East Bull Lake suite intrusions in the Southern Province have suggested shallow depths of emplacement (<8 km), possibly at the contact between the Archean basement and overlying supracrustal rocks of the Huronian Supergroup and its precursors (e.g., Card 1978; Peck et al. 1995; Vogel et al. 1998a, 1999). In contrast, researchers studying the River Valley intrusion have favoured moderate to deeper depths of emplacement (8-12 km), either at the boundary between Archean plutonic rocks and greenstone belts or at the boundary between gneisses and a plutonic-rock-dominated mid-crustal layer (e.g., Easton 2000; J.L. Hrominchuk, personal communication, 2000). Easton (2002b) went further, suggesting that several depths of emplacement are recorded within the East Bull Lake intrusive suite, based on the fact that the East Bull Lake intrusive suite bodies display subtly different features depending on which country rock gneiss association they are in contact with. This is illustrated schematically in Figure 4, where possible depth levels of emplacement of East Bull Lake suite intrusive rocks has been incorporated into the interpreted crustal section for the study area previously discussed in the section on "Country Rocks".

Two models have been proposed with respect to the emplacement mechanism of the East Bull Lake intrusive suite; both are discussed in James et al. (2002a), and are summarized here. The first model has been proposed specifically for the area extending from Elliot Lake to Sudbury. Based on geologic reconstruction and "unfolding" of the effects of Penokean deformation on the East Bull Lake and the Agnew Lake intrusions, and their similar stratigraphy, it has been proposed that the middle and upper parts of both these intrusions were part of an extensive, subhorizontal sheet. This sheet may have been approximately 2 km thick, representing the upper 75% of a lopolith that had horizontal dimensions of 30 to 50 km in a northerly direction and greater than 100 km in an easterly direction (James et al. 2002a; Vogel et al. 1999). In this model the lower and mineralized sections of the intrusions occupied rift fault-related structures or embayments that controlled magma intrusion, replenishment and mineralization, and thus, may not have been as widespread as the main mass of the lopolith. Furthermore, the mineralized zones would not have been connected. This model has been expanded to include the possibility that the East Bull Lake, Agnew Lake and River Valley intrusions, as well as the intervening smaller intrusions (*see* Figure 12, Appendix 4), are the remnants of one large interconnected Great Dike-like lopolith that can be traced for at least 300 km across central Ontario (*see* Figure 12) (James et al. 2002a). If so, then small size is not a concern in terms of modelling the potential size of mineralized sections, and the area of potential interest for exploration is much larger.

The second model proposes that the East Bull Lake intrusive suite was emplaced as a group of smaller, separate bodies, rather than as one or two large, now dismembered, sill complexes (James et al. 2002a). One consequence of this model is that the various bodies could have been emplaced at different crustal levels. This model would also provide an explanation for the differences in stratigraphy between the various intrusions, as not every intrusion would differentiate to the same degree. Finally, an important implication of this model is that mineralization style and grade will vary between intrusions. The author favours this model of separate intrusive bodies emplaced at different crustal levels.

MAGMA COMPOSITION AND ITS RELATIONSHIP TO MINERALIZATION

Detailed studies (Peck et al. 1995, 2001; Vogel et al. 1999; James et al. 2002a, 2002b) demonstrate that the magma(s) that formed the East Bull Lake and the Agnew Lake intrusions were high-Al, low-Ti (Al_2O_3~17.5 wt %; TiO_2~0.5 wt %) tholeiites. In these two intrusions, the main fractionation trend formed by leucogabbronorite and norites is interrupted by emplacement of more primitive, olivine-rich rocks (the Olivine Gabbronorite zones) which form a distinctive geochemical pattern not easily attributed to the same magma source.

In the case of the River Valley intrusion, at least north of the Sturgeon River, its stratigraphy (Figure 13), including the Olivine Gabbronorite, Gabbronorite and Leucogabbronorite zones, could be attributed to a magnesian variant (8-10% MgO) of the high-Al, low-Ti, tholeiite (James et al. 2002a). Such magma would have olivine followed by plagioclase on the liquidus, which satisfies the petrographic data for these rocks. The magma giving rise to the sporadically mineralized orthopyroxene-phyric norite and gabbronorite that is the main component of the Marginal Zone of the River Valley intrusion is part of an earlier magmatic sequence; its pyroxene-phyric, no olivine, character and disseminated PGE mineralization distinguish it from norites and gabbronorites higher in the stratigraphy (James et al. 2002a).

The magmatic evolution of the River Valley intrusion, however, is not as well constrained as it is for the East Bull Lake and Agnew Lake intrusions. As noted by Hrominchuk in James et al. (2002a), a unit of unlayered, medium-grained, orthopyroxene-phyric norite with a boninitic composition (MgO ~11.5 wt %, Al_2O_3 ~13.5 wt. %, SiO_2 ~51.5 wt %, *see* sample 99RME-2291, Appendix 3 and Figure 14), located near the southeast margin of the River Valley intrusion, could represent the parent magma of the intrusion. Furthermore, Hrominchuk argues that the Olivine Gabbronorite, Gabbronorite and

Leucogabbronorite zones formed from this boninitic parental magma by a combination of fractional crystallization and mixing of variably fractionated magma batches within the magma chamber. With the available data, it is equally plausible, however, that the Olivine Gabbronorite, Gabbronorite and Leucogabbronorite zones of the River Valley intrusion formed from a high-Al, low-Ti magma similar to that which produced the East Bull Lake and the Agnew Lake intrusions, and that the boninitic magma was only injected near the base of the intrusion to form the Marginal and Inclusion and/or Fragment-bearing zones (James et al. 2002a).

An argument against a boninitic parental magma is that such magmas are currently found in ocean island arc settings (e.g., Bonin islands, Japan, Papau New Guinea), unlike the inferred continental-rift plume-setting for the East Bull Lake intrusive suite. Nonetheless, boninites are thought to form from a relatively high degree of partial melting of previously melted metasomatized lithospheric mantle (Hamlyn et al. 1985). Metasomatism is generally thought to occur from fluids derived from dehydration of a subducted slab of oceanic crust (Hickey and Frey 1982), and can produce light rare earth element (LREE) enrichment in the resulting melt.

Alternatively, crustal contamination of a second-stage mantle melt can produce LREE enrichment in an otherwise primitive melt (Vogel et al. 1999). Vogel et al. (1999) found crustal contamination to be an unlikely mechanism for the uniform elevated LREE in the Agnew Lake intrusion, and suggested that the parent magma must have come from a partial mantle melt enriched by LREE-rich fluids. In the case of the River Valley intrusion, the LREE and trace element patterns are much less uniform and contamination is an important process, especially in the Marginal and Inclusion and/or Fragment-bearing zones (Hrominchuk 2000), which is one reason to favour a boninitic parental magma (James et al. 2002a). Regardless, both the proposed high-Al, low-Ti and boninitic parental magmas are second-stage, mantle-derived magmas as described by Hamlyn and Keays (1986).

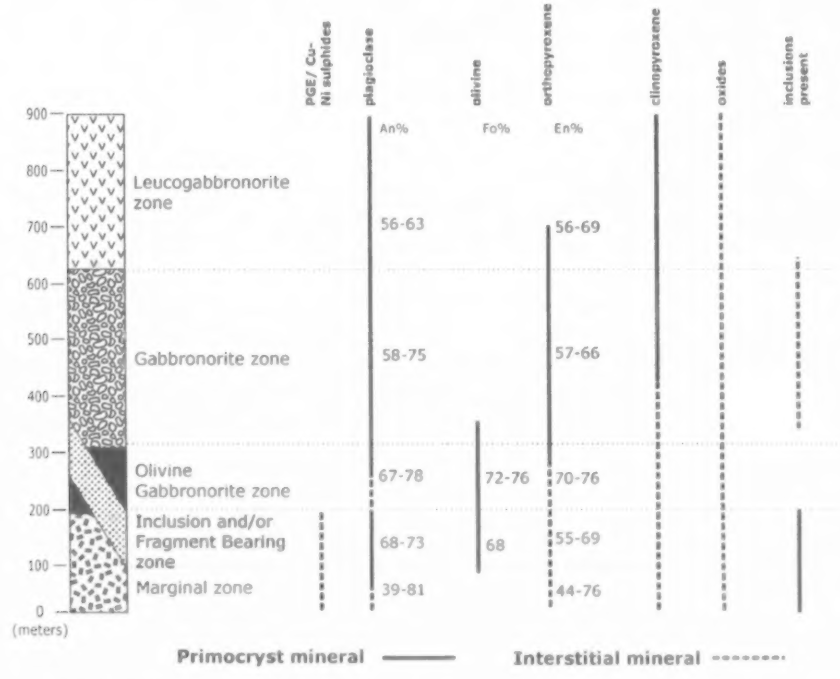

PGE/ Cu-Ni sulphides
plagioclase
olivine
orthopyroxene
clinopyroxene
oxides
inclusions present
An%
Fo%
En%
900
800
700
600
500
400
300
200
100
0
(meters)
Leucogabbronorite zone
Gabbronorite zone
Olivine Gabbronorite zone
Inclusion and/or Fragment Bearing zone
Marginal zone
56-63
56-69
58-75
57-66
67-78
72-76
70-76
68-73
68
55-69
39-81
44-76
Primocryst mineral
Interstitial mineral

Figure 13. Interpreted stratigraphic sequence and distribution of primary mineral phases and compositions within the River Valley intrusion north of the Sturgeon River. From James et al. (2002a).

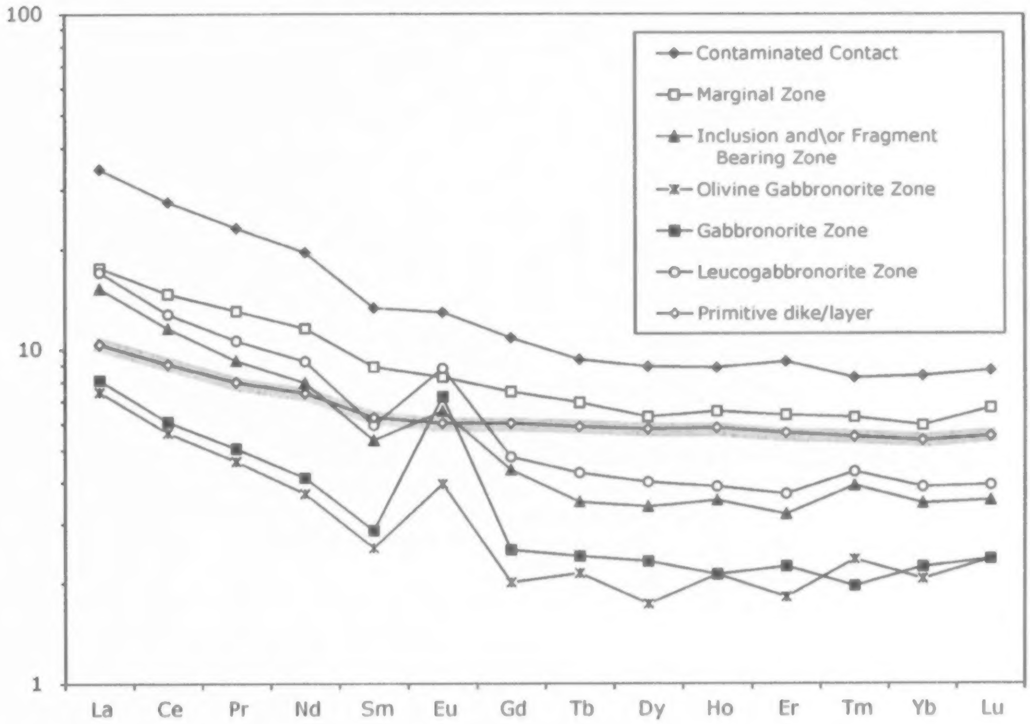


Figure 14. Chondrite-normalized rare earth element plots for the River Valley intrusion for rocks north of the Sturgeon River. Sample from the "primitive dike/layer" may represent the parent magma composition to the mineralized parts of the intrusion in Dana Township.

Hamlyn and Keays (1986) argued that second-stage magmas are critical to the formation of PGE deposits, a view also favoured in James et al. (2002a, 2002b). These fertile magmas arise from previously depleted mantle, typically in areas underlying Precambrian cratons or island arcs. Both the interpreted high-Al and boninitic parental magmas of the East Bull Lake intrusive suite are PGE fertile (Pt+Pd ~20-50 ppb) and S-poor (~100-200 ppm), and together with their continental rift-margin tectonic setting, are good examples of second-stage magmas. Their low S-content likely reflects prior extraction of MORB-type basalt liquids from the mantle, which removed most of the mantle sulphide component, but left a small amount of PGE-rich residual sulphide (Keays 1995). Pd and Se data for East Bull Lake intrusion (Peck et al. 2001) unmineralized cumulates and possible feeder dikes illustrates the PGE-rich nature of the parental magmas to the East Bull Lake intrusion compared to first-stage (MORB-type) magmas derived from fertile mantle; the latter have significantly higher S(Se) and lower PGE/S(Se) ratios.

In terms of crust-mantle scale processes, James et al. (2002a) suggested that fractional crystallization of a mantle-derived, second-stage magma in the lower to middle crust generated PGE-enriched, S-undersaturated leuconorite or norite magmas in the upper part of a zoned ultramafic to mafic magma chamber. During ascent and intrusion into the upper crust, this buoyant residual magma (parent to much of the East Bull Lake and Agnew Lake intrusions) became sulphur-saturated, and apparently escaped from the more primitive subchamber without sulphide loss. In this model, rocks of the more primitive Olivine Gabbronorite zone in the East Bull Lake and Agnew Lake intrusions represent influxes of magma from the more mafic parts of the same magmatic system. They should be relatively barren in PGE, except where mixing with fractionated liquids from the high-Al magmas may have generated reef-type deposits. Similar layered olivine-rich rocks in the River Valley intrusion appear to be part of a fractionating system that forms norites and leucogabbros in the upper part of this body (James et al. 2002a).

Detailed studies on PGE mineralization have been done only on the East Bull Lake intrusion. Many fine-grained gabbros in the Marginal Series and feeder-type plagioclase-phyric dikes in the footwall, have 20 to 100 ppb Pt+Pd (Pd/Pt =2:1 to 1:1) and contain small (< 1%) amounts of fine-grained disseminated sulphide (py±po±cpy). These PGE and sulphide contents are interpreted as evidence that early magma pulses were S-saturated when they entered the magma chamber (James et al. 2002a). The PGE values in these rocks far exceed those expected for basaltic liquids, even those derived from depleted mantle sources (Hamlyn and Keays 1986; Keays 1995), which is further evidence for S-saturation. Vigorous convection within the magma chamber, as evidenced by the Inclusion-bearing and Anorthosite zones at the East Bull Lake intrusion, produced high silicate/sulphide liquid mass ratios that allowed growing sulphide liquid droplets to attain the observed high PGE grades (1 to 10 g/tonne) (James et al. 2002a).

ORTHOPYROXENE HORNBLENDITE BODIES

Bodies of orthopyroxene hornblendite, consisting of centimetre-size orthopyroxene (bronzite) phenocrysts, ranging from 0.5 to 5 cm in length, hosted in a fine-grained amphibole-plagioclase matrix, have been previously described in detail from Street Township (Easton 1998, 1999a; Easton and Murphy 2002). Orthopyroxene hornblendite bodies are also known to occur throughout Awrey, Dryden, Henry and Loughrin townships (Easton 2002b; Davidson 1998). Large glacial erratics of orthopyroxene hornblendite, some up to 6 m across, are common in Henry, Loughrin and Street townships. The erratics are generally found within several hundred metres of observed bodies, or in areas where bodies may be hidden beneath overburden. They also occur at the contact of the Street metagabbro.

In most of these aforementioned townships, the orthopyroxene hornblendite bodies are found in close proximity to mafic intrusive rocks of the East Bull Lake intrusive suite. Zircon from an orthopyroxene hornblendite body in Street Township has been dated at 2468±5 Ma (Corfu and Easton 2000), similar in age to other intrusive rocks of the East Bull Lake intrusive suite (James et al. 2002a).

Even though some orthopyroxene hornblendite bodies occur within 100 m of the Grenville Front (Easton and Murphy 2002; Hubbard 1998), equivalent rocks to the orthopyroxene hornblendite bodies have not been reported in conjunction with East Bull Lake intrusive suite bodies located within the Southern Province. No orthopyroxene hornblendite bodies have been found in association with the River Valley intrusion, although some ultramafic layers present within the River Valley intrusion in Crerar Township are chemically similar to rocks of the orthopyroxene hornblendite suite, even though they are texturally and mineralogically distinct. Easton (2002b) suggested that the orthopyroxene hornblendite bodies are restricted to the Street gneiss association, although some bodies do occur in association with other East Bull Lake intrusive suite rocks along the boundary between the Street and Crerar gneiss associations. This would explain the absence of these rocks in the Southern Province and in association with the River Valley intrusion, as well as their abundance in Awrey, Dryden, Henry, Loughrin and Street townships, all of which are underlain by rocks of the Street gneiss association.

Easton and Murphy (2002) suggested that these bodies exhibited only 2 types of contact relationships, however, work by Easton (2002b) suggests that there may be 4 types of contact relationships. These contact types are summarized below:

1. The first type occur near sharp, possibly modified igneous contacts between metagabbroic and metaleucogabbroic rocks of the East Bull Lake intrusive suite and their host gneisses (Street gneiss association). Bodies of this type appear to have been emplaced into pre-existing embayments along the metagabbro-gneiss contact. All of the Street Township bodies are of this type.
2. The second type occurs within deformation zones characterized by flattened gneissic rocks (e.g., the body exposed on the south side of Highway 17 in Awrey Township).

3. Some bodies, such as body H3 (*see* Figure 2) in Loughrin Township, show a linear distribution and may represent boudinaged dikes. It is possible that types 2 and 3 are related, with type 2 representing a more deformed version of type 3.
4. Many of the larger bodies found in Henry and Loughrin townships, are not clearly associated with the contact of the River Valley intrusion, for example, bodies H1, H2 and H4 on Figure 2 are located over 1 kilometre from the contact.

The field term for these rocks, orthopyroxene hornblendite, is based on the dominant mineral phases observed in hand sample for these rocks. Some of the better-preserved bodies contain relict olivine grains. Mesonorm calculations suggest a metamorphic mineralogy dominated by pyroxene and amphibole consistent with the observed mineralogy in the field. CIPW normative calculations for these rocks suggest a primary mineral assemblage dominated by olivine (4-22%), hypersthene (32-62%), diopside (3-22%) and calcic plagioclase (13-21%) (Easton and Murphy 2002). The CIPW normative mineralogy suggests that these rocks were originally olivine gabbronorites or olivine websterites, depending on whether they contained moderate or only minor amounts of plagioclase, respectively.

Orthopyroxene hornblendite bodies located near the Grenville Front contain euhedral bronzite grains up to 5 cm long (Photos 21, 22a, 22b). The bronzite grains become subrounded to rounded and overall grain size decreases with increasing distance from the Grenville Front. Similar observations can be observed from the margin to the core in some of the smaller hornblendite bodies. This change in bronzite form with increasing distance into the Grenville Province can be attributed to greater degrees of metamorphic recrystallization toward the interior of the Grenville Province.

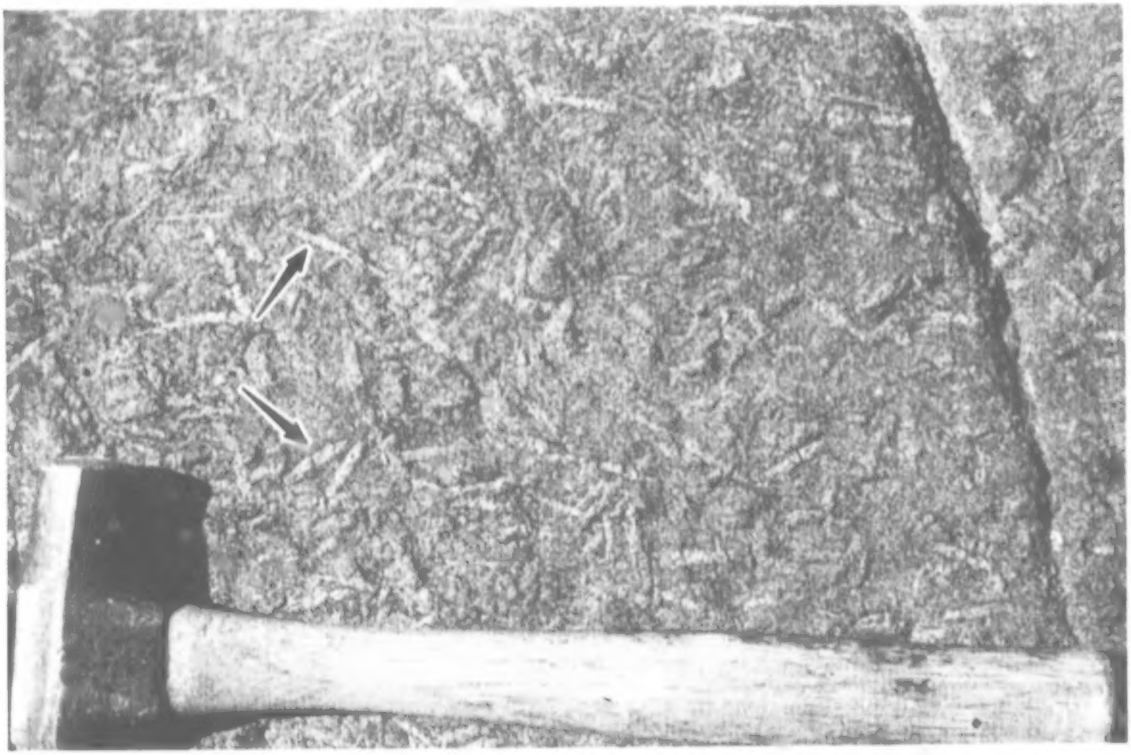


Photo 21. Elongate orthopyroxene phenocrysts in orthopyroxene hornblendite (body H3, *see* Figure 2). Hammer handle is 30 cm long. Station 02RME-0156. UTM 534909E 5157716N.

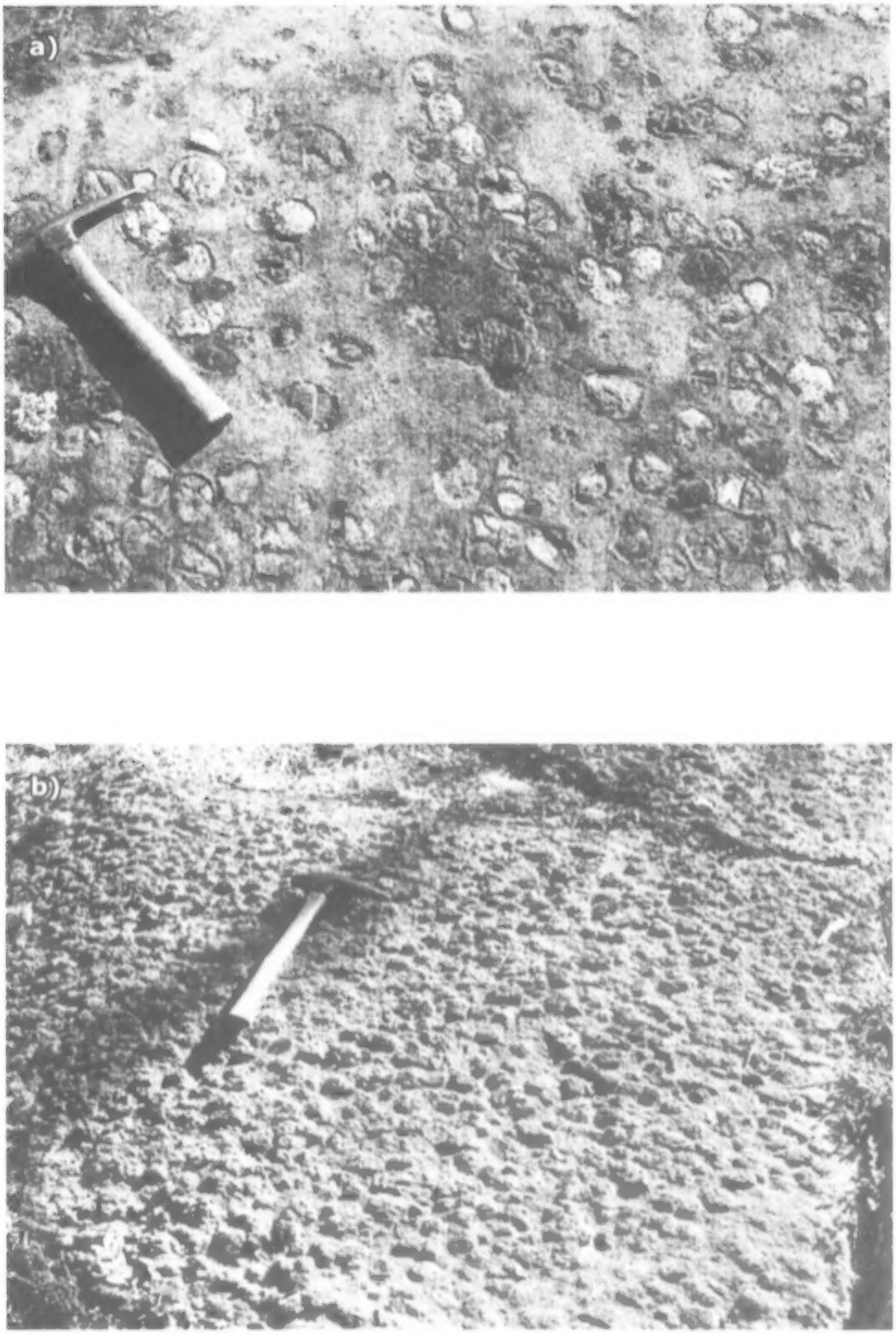


Photo 22. **a)** Orthopyroxene phenocrysts in matrix-rich orthopyroxene hornblendite (body H7, *see* Figure 2). Hammer handle is 30 cm long. Station 02RME-0401. UTM 547314E 5158815N. **b)** More typical size and distribution of orthopyroxene phenocrysts in an orthopyroxene hornblendite body (body H7, *see* Figure 2). Hammer handle is 30 cm long. Station 02RME-0401. UTM 547354E 5158772N.

Mineralogically, the orthopyroxene crystals in the bodies are complex and represent primary phenocrysts that recrystallized during regional metamorphism. Evidence that these crystals were primary phenocrysts comes from the presence of zircon and chromite inclusions within the bronzite grains. Both types of inclusions contain well-developed cores and rims. In the case of the zircon grains, subrounded cores are surrounded by euhedral fractured rims. The cores yielded the aforementioned U/Pb age of 2468±5 Ma, whereas the rims yielded an age of 1471±10 Ma (Corfu and Easton 2000). Chromite cores are rimmed by iron chromite that typically forms only during regional metamorphism (Deer, Howie and Zussman 1966). Small euhedral zircons are also present in the fine-grained amphibole matrix and yielded an age of 1052±19Ma (Corfu and Easton 2000).

Mineral chemistry data on the matrix amphiboles indicates that they are magnesium hornblende, tremolite, cummingtonite and magnesium cummingtonite. The amphiboles occur both as individual grains and complexly exsolved and intergrown grains. Olivine grains from a body located near the Grenville Front have compositions of Fo_{73}. Orthopyroxene compositions lie in the bronzite field and are magnesium-rich (En_{75-80}) (Easton and Murphy 2002; Hubbard 1998).

Geochemistry

Analyses from 11 separate bodies show only a limited compositional range in major element chemistry (*see* Appendix 3). The SiO_2 content of the unaltered orthopyroxene hornblendites ranges from 46.0 to 50.5 weight percent which is unusually high given the corresponding MgO content of 21.0 to 27.0 weight percent. Figures 15 and 16 briefly summarize the chemistry of these rocks. On a Jensen diagram (Figure 15b) the orthopyroxene hornblendites plot as a cluster in the peridotitic komatiite field although there is no evidence to suggest that these rocks were extrusive. Plots of Ti versus Cr and Cr-Ni (not shown) are consistent with these rocks being crystallized from layered mafic sills.

Orthopyroxene hornblendite samples plot in 2 distinct groups on a chondrite-normalized rare earth element diagram (*see* Figure 16). One group has relatively flat, 10 times chondrite pattern with a negative Eu anomaly and total REE less than 35 ppm, whereas the second group has moderate LREE enrichment (to 60 times chondrite), no Eu anomaly, and total REE greater than 80 ppm. REE contents of the first group are similar to, or higher than, those observed in gabbronoritic rocks of the Street metagabbro. The REE content and high silica content of the orthopyroxene hornblendites suggest the orthopyroxene hornblendites do not represent the most primitive rocks of the East Bull Lake intrusive suite.

The first group, characterized by low total REE contents and magnesium contents greater than 20 weight percent, occur as isolated bodies, near, but not intimately associated with other East Bull Lake intrusive suite rocks. In contrast, the second group with the higher REE contents and lower magnesium contents (<19.0 wt. %) occur at primary intrusive contacts, or as layers within East Bull Lake intrusive suite bodies. For example, the hornblendite samples from the Street metagabbro plot in the LREE enriched group, as do olivine gabbronorites and pyroxenites from the River Valley intrusion. It can be argued that the two groups are related to one another, with the lower magnesium group being a more fractionated differentiate of the magma that produces these unusual rocks.

All 10 unaltered orthopyroxene hornblendite samples contain from 2900 to 4700 ppm Cr and 750 to 1000 pm Ni. Copper content is generally low (*see* Appendix 3) although samples 96RME-0041 and 97RME-0036 contain 160 ppm Cu and 215 ppm Cu, respectively. Chromium is present as chromium-spinel, iron-chromite and chromite and is concentrated within the olivine and orthopyroxene crystals present in these rocks. Platinum group element content in all of the analyzed orthopyroxene hornblendite samples is low (generally at or below detection limits), regardless of degree of alteration. The orthopyroxene hornblendites differ from other rocks of the East Bull Lake intrusive suite in their high chromium and nickel contents, as listed above. One explanation for this difference is that precipitation and removal of pyroxene from the primary magma (possibly by crystal settling) increases the silica content of the melt. The increase in silica would move the composition of the melt away from the olivine-chromite cotectic into the field of chromite and lead to the co-precipitation of bronzite and chromite. This process, in conjunction with olivine precipitation, would effectively strip the primary magma of much of its chromium and nickel leaving rocks of the East Bull Lake intrusive suite with low chromium and nickel contents.

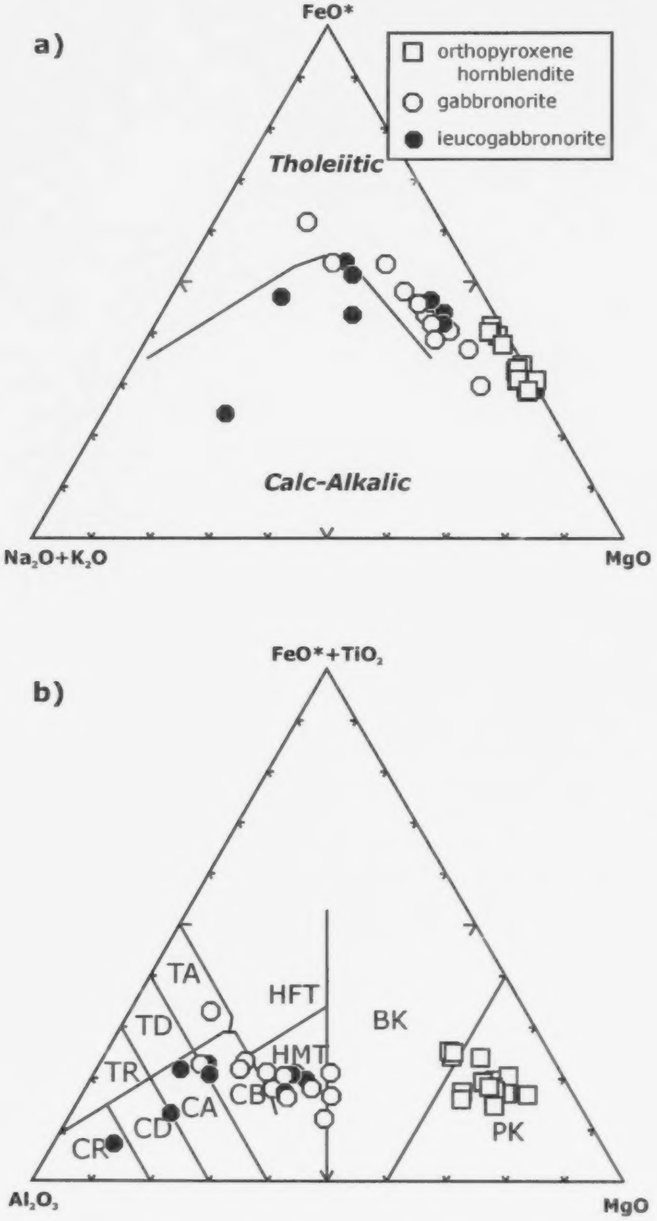


Figure 15. AFM (upper) and Jensen (lower) diagrams for orthopyroxene hornblendites from the study area. Other East Bull Lake intrusive suite rocks from Street Township are shown for comparison.

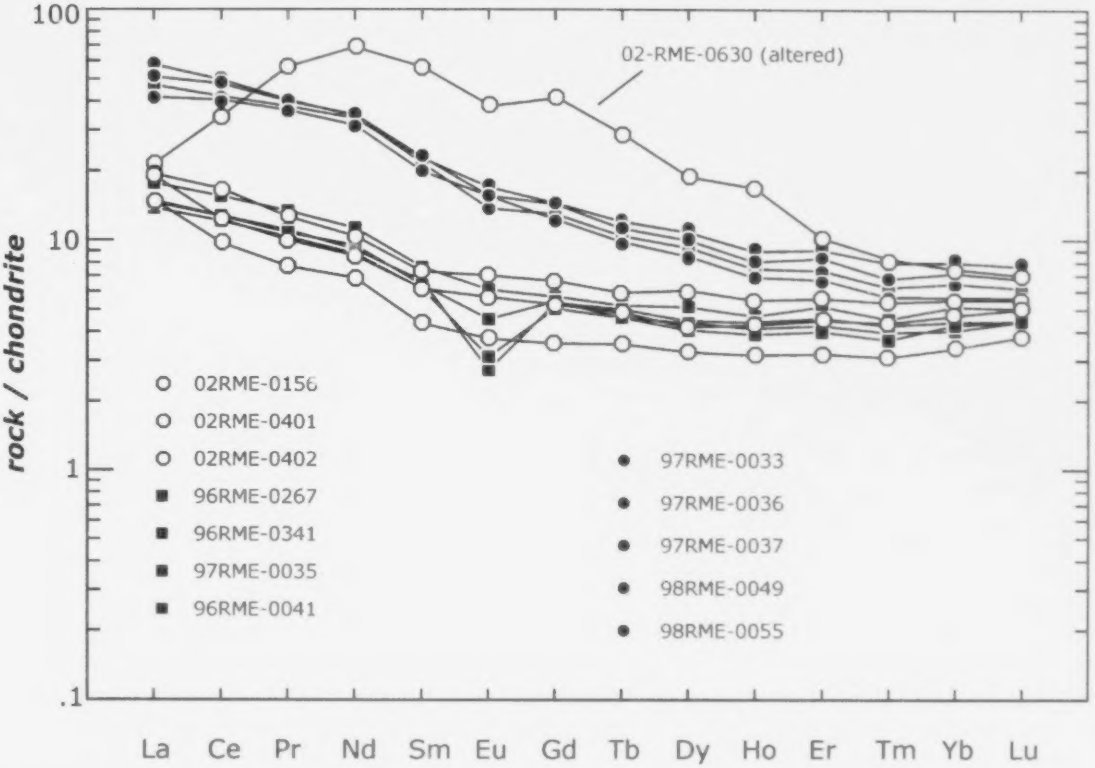


Figure 16. Chondrite-normalized rare earth element plots for 11 orthopyroxene hornblendite samples from the study area. Note the orthopyroxene hornblendites fall into two groups, one characterized by prominent Eu anomalies and only slightly enriched LREE contents, the other characterized by moderately enriched LREE contents and no Eu anomaly. The rare earth element patterns for both groups of hornblendites are similar to those for other East Bull Lake intrusive rocks (*see* Figures 5 and 14), however, the hornblendites are not the most primitive rocks within the East Bull Lake intrusive suite. In combination with the trace element chemistry of the hornblendites (e.g., Zr, Y, P contents) the rare earth element data suggest that the orthopyroxene hornblendites were derived from evolved, rather than primitive, magmas.

Sample 02RME-0360 (*see* Appendix 3) is likely altered, as it is characterized by unusual enrichment in Ce, Pr, Nd, Sm, Eu and Gd (*see* Figure 16), as well as CaO, CO_2 and Sr. It is found at the boundary between the Street and Crerar gneiss associations, and the observed alteration could be related to hydrothermal fluid activity along this boundary prior to regional metamorphism. This sample is also characterized by lower than normal Cr and Ni contents.

Chromium numbers of the orthopyroxene hornblendites are 20 to 38 and magnesium numbers are 78 to 82. The bodies have chemical affinities to high-aluminum chromitite from ophiolitic complexes, most notably, chromium number less than 50, TiO_2 greater than 0.2 weight percent, CaO greater than 1.5 weight percent, and Al_2O_3 greater than 1.2 weight percent. High aluminum chromitites are found in back-arc spreading and rifting tectonic environments that are consistent with previous suggestions of a rift-setting for the lower Huronian Supergroup (e.g., Bennett, Dressler and Robertson 1991).

RIVER VALLEY INTRUSION

Form and Geometry

The River Valley intrusion is located about 65 km east-northeast of Sudbury (*see* Figure 12) near the community of River Valley. The intrusion underlies parts of Crerar, Dana, Henry, Janes and McWilliams townships, but is best exposed in Dana Township, where it locally contains well-preserved primary mineralogy and textures (Hrominchuk 1999, 2000; Easton and Hrominchuk 1999, 2001a, 2001b).

Of all the East Bull Lake intrusive suite bodies studied to date, the River Valley intrusion shows the clearest relationships with other members of the Paleoproterozoic rifting suite described earlier. It is cut by mafic dikes geochemically correlated with the Matachewan and Hearst dike swarms, as well as by felsic intrusive rocks coeval with the Huronian Supergroup volcanic rocks (Easton and Hrominchuk 1999, 2001b). Furthermore, in Street Township, granitic rocks dated at 2460±20 Ma, contain inclusions of East Bull Lake intrusive suite leucogabbroic and anorthositic rocks (Easton and Murphy 2002). Similar inclusions have also been observed by the author in granitic plutons in Henry and Loughrin townships. Unfortunately, the relationship between the River Valley intrusion and the Huronian Supergroup is obscured by tectonism along the Grenville Front.

Along the Grenville Front, the River Valley intrusion is either in thrust contact with quartzite of the Mississagi Formation (Davidson 1986) or is in an unknown contact relationship with mafic and felsic metavolcanic rocks of the lower Huronian Supergroup (Easton and Hrominchuk 1999). On the basis of geochemical correlation, however, these metavolcanic rocks are likely ~2460 Ma in age (Easton and Hrominchuk 1999), and consequently, most likely were deposited after emplacement of the River Valley intrusion. The River Valley intrusion is also cut by olivine diabase dikes of the 1238 Ma Sudbury dike swarm (Easton 2000) and the 590 Ma Grenville dike swarm.

Intrusive contacts between the River Valley intrusion and the Archean basement are exposed throughout the eastern half of the intrusion, and are generally sharp (Photo 23). Zones of intense diking, equivalent to the Border Zone in the East Bull Lake intrusion have not been observed. In fact, in both Dana and Crerar townships, Archean para- and orthogneisses adjacent to the intrusion are devoid of any mafic dikes, apart from a few Matachewan-Hearst swarm diabase dikes. In some parts of Dana Township, a fine- to medium-grained gabbro is present at the contact, and may represent a chilled facies of the intrusion. In many areas, however, an inclusion- and/or fragment-bearing facies occurs proximal to the contact, making it difficult to ascertain the true extent and significance of this finer-grained facies.

As in the case of the East Bull Lake intrusion, a "syenite" (actually an alkali feldspar granite) body in Dana Township was originally interpreted as a felsic differentiate of the River Valley intrusion (e.g., Card and Lumbers 1975). On the basis of contact relationships and geochemistry, Easton (2000) interpreted it as Archean in age, an interpretation that has been recently confirmed by U/Pb zircon dating, which yielded a preliminary age of 2640 Ma (S. Kamo, Geochronologist, Jack Satterly Geochronology Laboratory, Royal Ontario Museum, unpublished data, 2003).

Previous maps of the River Valley intrusion (e.g., Lumbers 1973; Card and Lumbers 1975) showed the River Valley intrusion extending west into Henry and Loughrin townships as a series of "tails" surrounded by gneissic country rocks. This map pattern was interpreted to be the result of either

1. a pattern of complex interference folding during Penokean and Grenvillian orogenesis, or
2. a system of feeders to the main body of the intrusion located in Crerar and Dana townships.

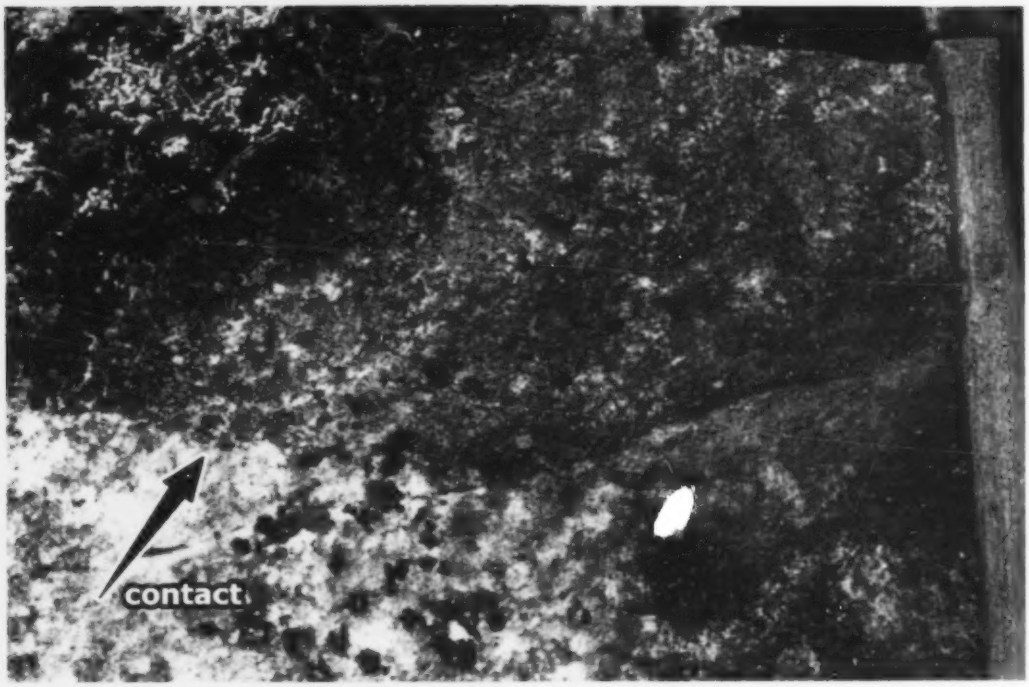


Photo 23. Exposed, sharp contact between gabbronorite of the River Valley intrusion (top) and altered alkali-feldspar granite (bottom, light coloured) in Crerar Township. Hammer handle is 30 cm long. Station 99RME-0578. UTM 559273E 5160815N.

Furthermore, it was also speculated that other isolated bodies of East Bull Lake intrusive suite rocks in the Grenville Province, west of the River Valley intrusion (e.g., Red Deer Lake, Street Twp., southern Wanapitei Complex, *see* Appendix 4), may represent parts of the River Valley intrusion now isolated from the main mass through erosion and tectonism. Work conducted during this study, first reported in Easton (2002b), suggests otherwise. The East Bull Lake intrusive rocks located west of Crerar Township are different in form, stratigraphy, overall composition, and are intruded into distinctively different country rocks, than those found in the River Valley intrusion. Consequently, the author believes that the East Bull Lake intrusive suite rocks located west of Crerar Township represent parts of one or more intrusions that were emplaced separately from the River Valley intrusion. These separate intrusions are described in subsequent sections of this report.

STRUCTURAL STATE AND DEGREE OF PRESERVATION

Figure 17 outlines the general structural state of the River Valley intrusion and the country rocks in Dana and Crerar townships, as well as the degree of textural preservation within the intrusion and the country rocks. Seven main preservation regimes can be recognized, which are described in Table 9; these form the basis of the divisions shown in Figure 17.

The Sturgeon River, and the Neoproterozoic to early Paleozoic fault along it, is an important structural feature within the River Valley intrusion (*see* Figure 17). North of the Sturgeon River, the River Valley intrusion contains large areas of preserved or partly preserved primary mineralogy, and deformation is concentrated along discrete shear zones, both vertical and sub-horizontal, that cut the intrusion (Easton and Hrominchuk 1999, 2001b; Hrominchuk 2000). Grenvillian deformation is largely concentrated near the Grenville Front, along the west side of the intrusion (*see* Figure 17). North of the Sturgeon River, Grenvillian metamorphism results in the incipient development of corona textures in rocks of the River Valley intrusion and the Sudbury diabase dike swarm, with metamorphic conditions estimated at 5 to 7 kb and 625°C (Tettelaar 2000; Easton and Hromincuk 1999). An empirical observation is that rocks of leucogabbroic composition are most commonly recrystallized, whereas orthopyroxene-bearing rocks are generally more resistant to metamorphic recrystallization. The geometry of the intrusion north of the Sturgeon River appears to be largely sheet-like, with igneous layering generally dipping shallowly (20-30°) to the south and southeast. This has resulted in exposure of the basal contact of the River Valley intrusion for 8 to 10 km along the northern and eastern margin of the intrusion, providing an extensive target area for mineral exploration.

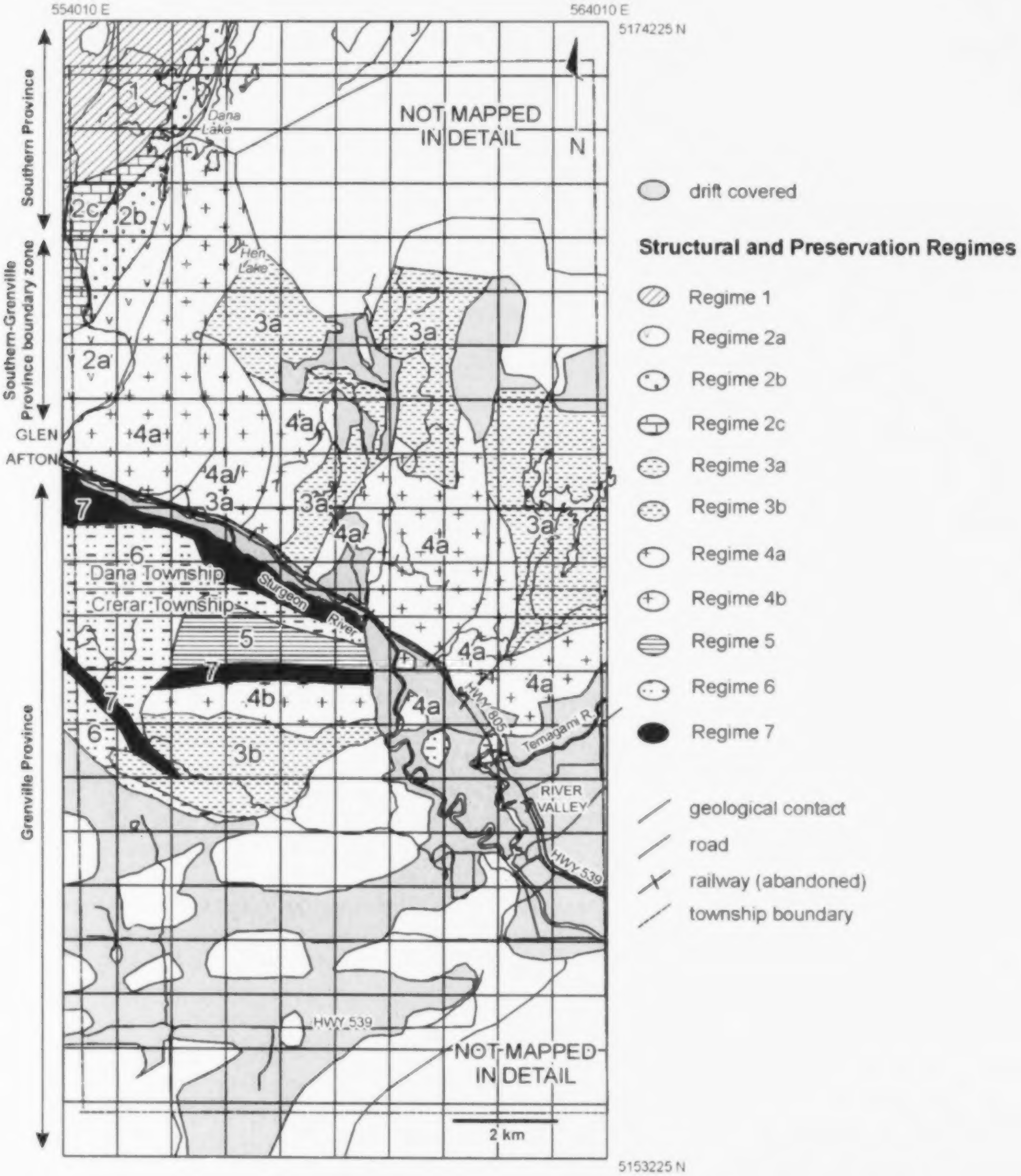

554010 E
564010 E
5174225 N
5153225 N
N
NOT MAPPED IN DETAIL
Southern Province
Southern-Grenville Province boundary zone
Grenville Province
GLEN AFTON
Dana Lake
Hen Lake
Dana Township
Crerar Township
Sturgeon River
Temagami R.
RIVER VALLEY
HWY 805
HWY 539
2 km
1
2a
2b
2c
3a
3b
4a
4b
5
6
7
drift covered
Structural and Preservation Regimes
Regime 1
Regime 2a
Regime 2b
Regime 2c
Regime 3a
Regime 3b
Regime 4a
Regime 4b
Regime 5
Regime 6
Regime 7
geological contact
road
railway (abandoned)
township boundary

Figure 17. Map showing the degree of primary textural preservation within rocks of Crerar and Dana townships. See Table 9 for descriptions of the different preservation regimes illustrated on the map.

Table 9. Description of preservation regimes for the River Valley intrusion, as illustrated in Figure 17.

Type	Character of Best Preserved Rocks	Character of Most Deformed Rocks	Structural Style	Metamorphic Conditions (Grenville?)	Location
1	unfoliated but recrystallized (green amphibole).	ultramylonite	discrete ultramylonite zones along unit contacts (thrust faults?), minor ultramylonite zones.	lower to upper greenschist	Southern Province
2a	preserved igneous textures and mineralogy (e.g., orthopyroxene). Where recrystallized, green amphibole.	ultramylonite	anastomosing shear zones, largest intact lozenges 1 km wide by 2 km long, generally smaller, intact lozenges are commonly topographic highs.	upper greenschist to lower amphibolite	Southern-Grenville Province boundary zone
2b	unfoliated but recrystallized (green amphibole).	ultramylonite	anastomosing shear zones, largest intact lozenges 1km wide by 2 km long, generally smaller, intact lozenges are commonly topographic highs.	upper greenschist to lower amphibolite	Southern-Grenville Province boundary zone
2c	protomylonite.	ultramylonite	shear zone, with some intact lozenges where original protolith can tentatively be identified.	upper greenschist to lower amphibolite	Southern-Grenville Province boundary zone
3a	preserved igneous textures and mineralogy (e.g., olivine, orthopyroxene). Where recrystallized, green amphibole.	irregular gneiss	anastomosing shear zones, largest intact lozenges 1 to 2 km wide by 5 km long, intact lozenges are commonly topographic highs.	middle to upper amphibolite. Corona texture and clouded feldspar.	Eastern and central Dana twps.
3b	preserved igneous textures and mineralogy (e.g., olivine, orthopyroxene). Where recrystallized, black amphibole, amphiboles commonly have cores.	irregular gneiss	anastomosing shear zones, largest intact lozenges 1 to 2 km wide by 5 km long, intact lozenges are commonly topographic highs.	upper amphibolite Well-developed corona texture and clouded feldspar.	Southwest part of River Valley intrusion Crerar Twp.
4a	unfoliated but recrystallized (green amphibole).	irregular to straight gneiss	anastomosing shear zones, largest intact lozenges 750 m by 1 km, generally smaller, intact lozenges are commonly topographic highs.	lower amphibolite	Parts of Dana Twp.
4b	unfoliated but recrystallized (black amphibole, amphiboles commonly have cores).	irregular to straight gneiss	anastomosing shear zones, largest intact lozenges 750 m by 1 km, generally smaller, intact lozenges are commonly topographic highs.	middle to upper amphibolite	central part of River Valley intrusion in Crerar Twp.
5	weakly foliated but recrystallized (black amphibole, amphiboles commonly have cores).	straight gneiss	anastomosing shear zones, largest intact lozenges 750 m by 1 km, generally smaller, intact lozenges are commonly topographic highs.	upper amphibolite	west-central River Valley intrusion in Crerar Twp.
6	gneissic, black amphibole, garnet, scapolite, calc-silicates.	straight gneiss	regional gneissosity, some mafic dikes cut gneissosity, regional and outcrop-scale refolded folds of gneissosity.	upper amphibolite	River Valley intrusion in west-central Crerar Twp.
7	flattened gneissic fabric, black amhibole, garnet, scapolite, calc-silicates.	straight gneiss	extremely flattened gneissic fabric, irregular to straight gneiss.	upper amphibolite	River Valley intrusion in Crerar Twp.

In contrast, south of the Sturgeon River, pockets of preserved mineralogy and texture are less abundant, occurring mainly in eastern Crerar Township (*see* Figure 17). Where present, igneous layering dips moderately (40° to 60°), and stratigraphy is apparently folded (Easton and Hrominchuk 2001a). This folding results in a variety of trends for the basal, mineralized contact of the intrusion, making mineral exploration more difficult than in the north. Penetrative fabrics of Grenvillian-age are common, with much of the River Valley intrusion consisting of gneissic rocks of gabbroic and leucogabbroic composition. Grenvillian metamorphic effects result in more complete development of corona textures in rocks of both the River Valley intrusion and the Sudbury diabase dike swarm in Crerar Township, with metamorphic conditions estimated at 7 to 9 kb and 650°C (Tettelaar 2000; Easton and Hrominchuk 1999).

Igneous layering at several scales is preserved within the River Valley intrusion (Photos 24a to 24d). Photos 25a to 25d and 26a to 26d illustrate the textural changes that occur within rocks of the River Valley intrusion with increasing metamorphic recrystallization and deformation. Other textures preserved in the intrusion are shown in Photos 27 and 28.

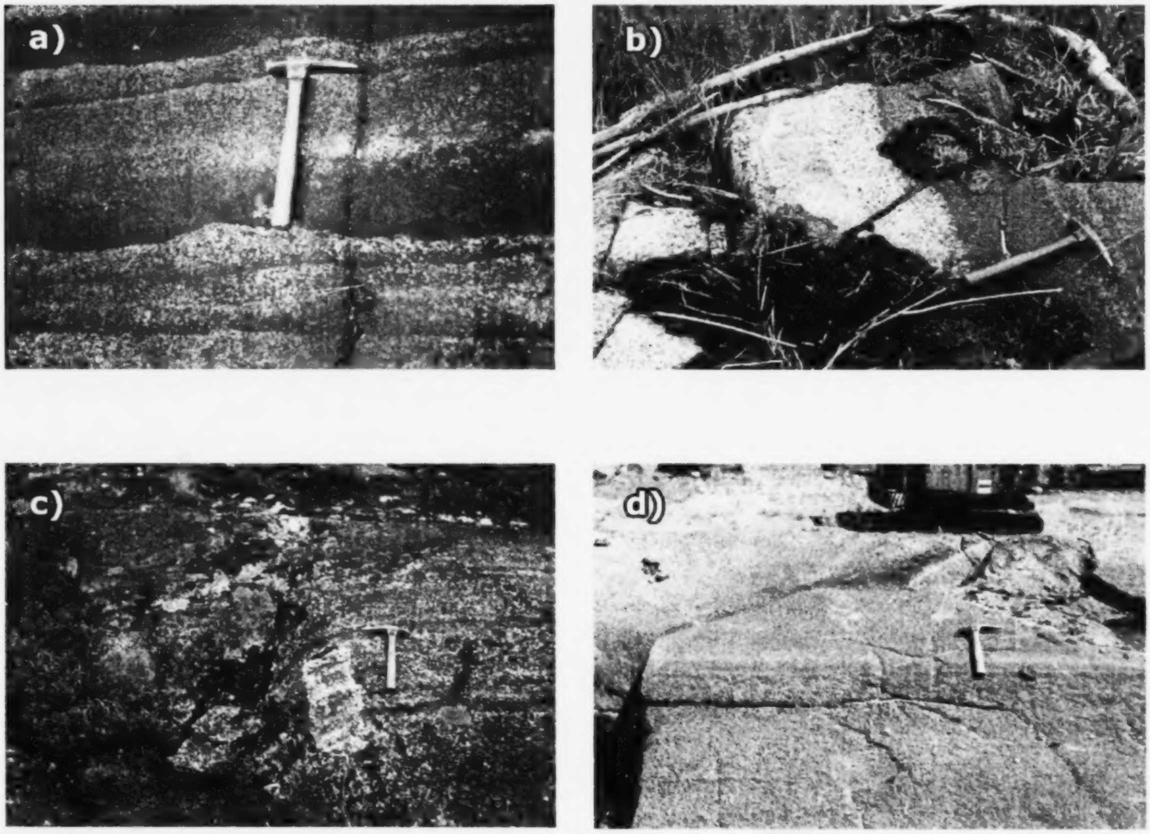


Photo 24. Igneous Layering **a)** Igneous layering within the norite zone, River Valley intrusion, Crerar Township. Hammer handle is 30 cm long. Station 99RME-0392. UTM 556769E 5159980N. **b)** Igneous layering within the River Valley intrusion in Crerar Township, near the top of the anorthosite zone and the base of the olivine gabbronorite zone. Dark layers are melanorites, some of which are olivine-bearing. Hammer handle is 30 cm long. Station 99RME-0523. UTM 557390E 5160360N. **c)** Layering within leucogabbronoritic rocks immediately above the heterogeneous basal zone of the River Valley intrusion, Crerar Township. Hammer handle is 30 cm long. Station 99RME-0546. UTM 557585E 5159590N. **d)** Large-scale igneous layering within leucogabbronoritic rocks of the River Valley intrusion exposed in the Dana Quarry, Dana Township. Hammer handle is 30 cm long. UTM 558630E 5165385N.

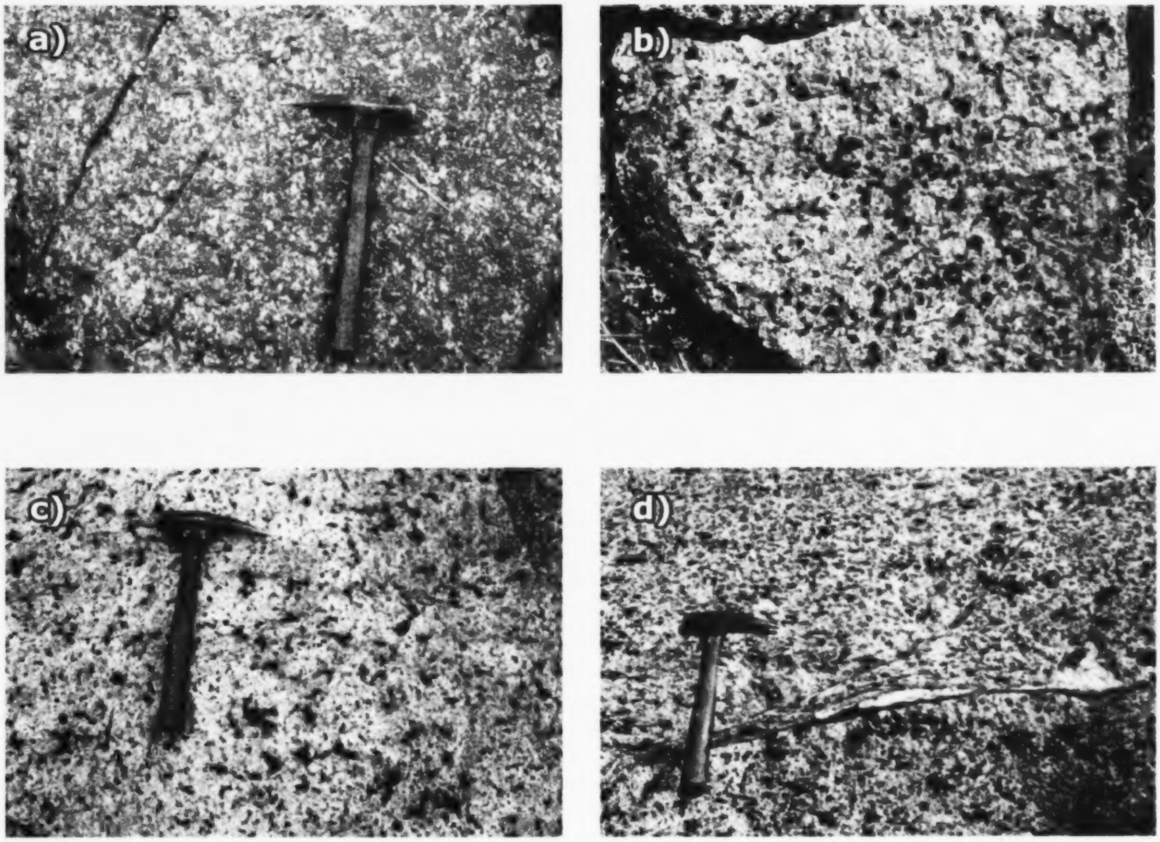


Photo 25. Progressive textural changes. a) Igneous texture in medium-grained norite from leucogabbronorite zone of the River Valley intrusion, Crerar Township. Note dark colour of feldspars. Hammer handle is 30 cm long. Station 99RME-0314. UTM556115E 5171466N. **b)** Partly recrystallized rock of the River Valley intrusion, preserving igneous texture in medium-grained gabbronorite from leucogabbronorite zone of the River Valley intrusion, Crerar Township. Mafic minerals have thick, green-weathering amphibole coronas rimming dark orthopyroxene grains. Station 99RME-0463. UTM 556886E 5161009N. **c)** Recrystallized but unfoliated leucogabbronorite from leucogabbronorite zone of the River Valley intrusion, Crerar Township. This rock no longer preserves primary mineralogy, but is relatively undeformed. Note white colour of feldpars, and lack of well defined crystal shapes. Mafic mineral clots are aggregates of fine-grained amphibole. Hammer handle is 30 cm long. Station 99RME-0513. UTM 557400E 5160225N. **d)** Typical undeformed but recrystallized leucogabbronotite from the Positano Quarry, East Bull Lake intrusive suite, Loughrin Township. Station 02RME-0105. UTM 547000E 5160600N.

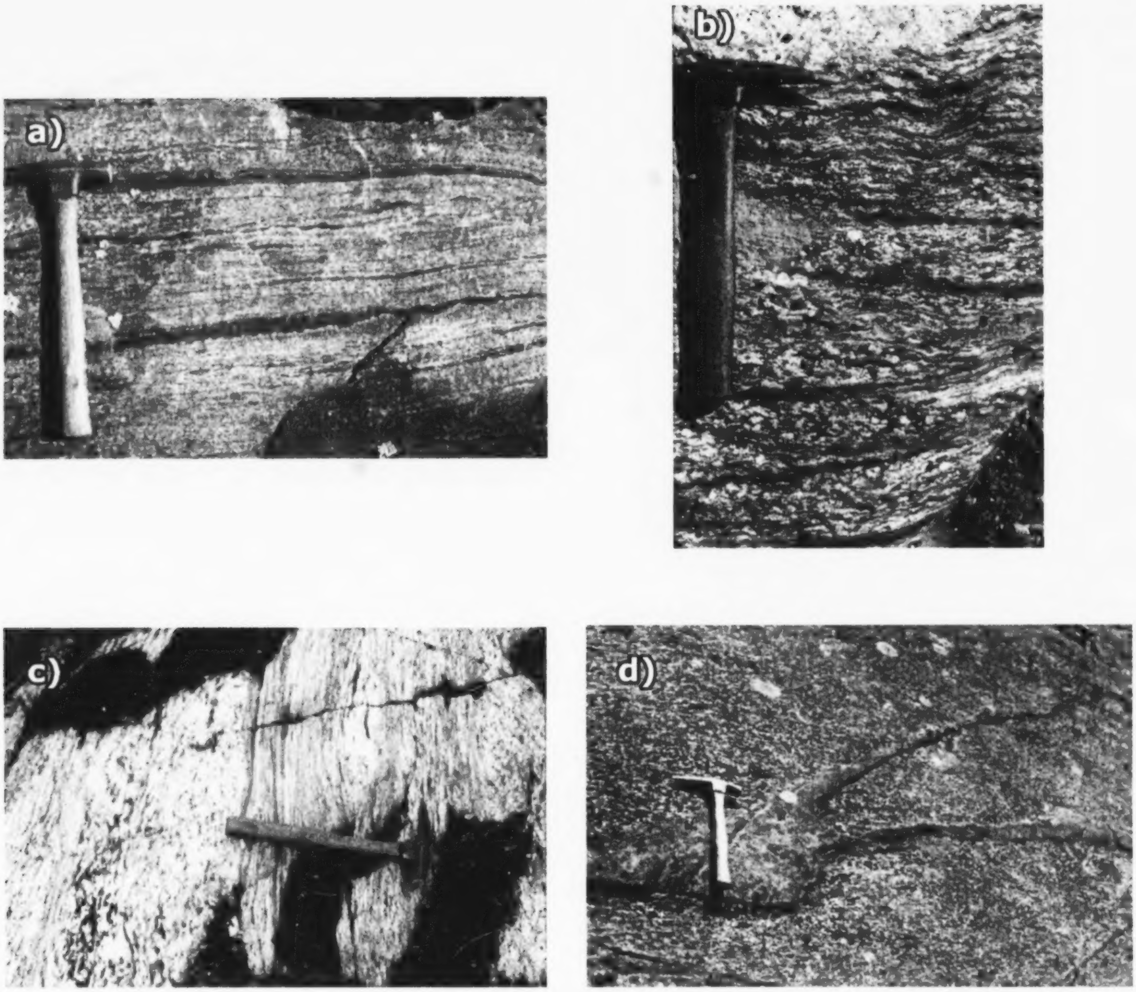


Photo 26. a) Typical leucogabbroic gneiss of the East Bull Lake intrusive suite intrusion within Henry and Loughrin townships. Note the lack of a prominent leucosome phase, either parallel to or discordant to gneissosity (compare with Photo 8). Hammer handle is 30 cm long. Station 02RME-0335. UTM 548443E 5159789N. **b)** Protomylonitic to mylonitic textures present in a high-strain zone in the River Valley intrusion, Crerar Township. Hammer handle is 30 cm long. Station 99RME-0585. UTM 559751E 5163890N. **c)** Strain gradient within rocks of the River Valley intrusion, northern Crerar Township. Foliated to gneissic leucograbbro on top, straight and irregularly layered gneiss on bottom. Hammer handle is 30 cm long. Station 99RME-0750. UTM 557225E 5162512N. **d)** Epidote clot developed just right of the hammer handle in leucogabbro gneiss of the River Valley intrusion, Crerar Township. Such epidote clots are common in gneissic leucogabbro throughout the study area. Hammer handle is 30 cm long. Station 99RME-0298. UTM 555495E 5163580N.

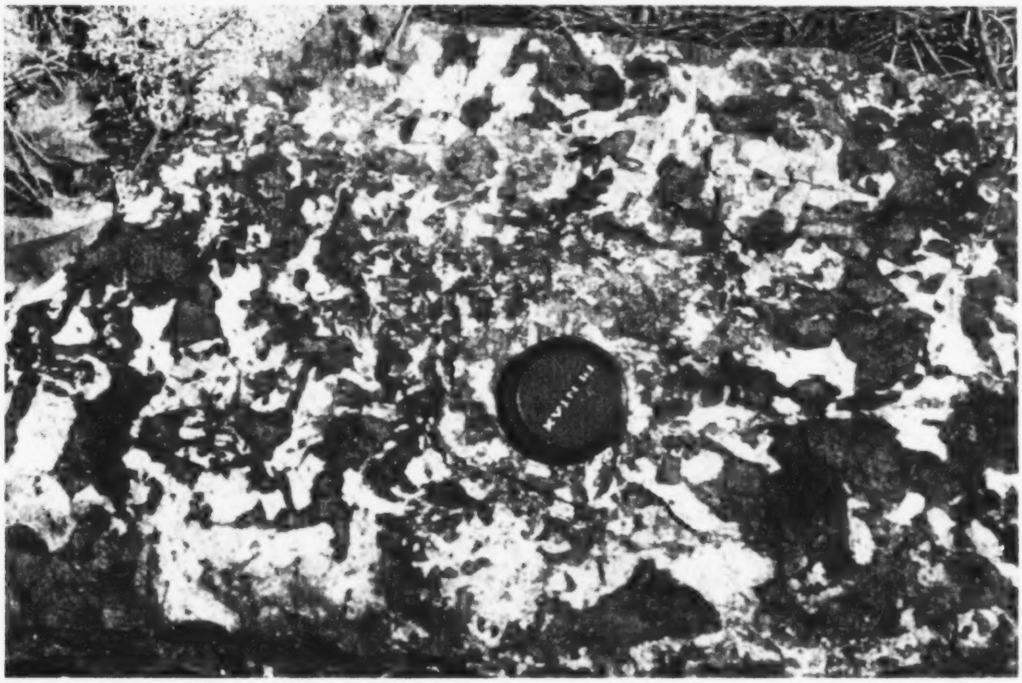


Photo 27. Coarse-grained, vari-textured gabbronorite of the River Valley intrusion in Crerar Township. Mafic minerals have orthopyroxene cores and fine-grained amphibole rims. Lens cap is 55 mm in diameter. Station 99RME-0463. UTM 556886E 5161009N.

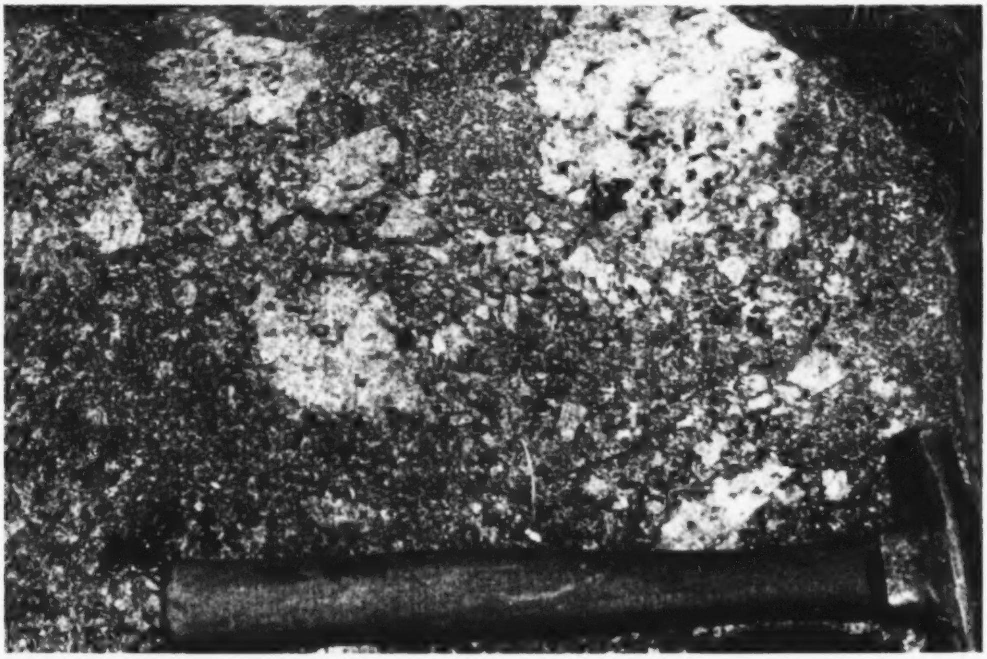


Photo 28. Nodular anorthosite fragments within gabbronorite of the River Valley intrusion, Crerar Township. Hammer handle is 30 cm long. Station 99RME-0398. UTM 556383E 5160243N.

CONTACTS

Copper, nickel and platinum group element exploration in the River Valley intrusion has focussed on the contacts of the intrusion, as outlined by Lumbers (1973). This is only an effective exploration tool if the contacts of the intrusion are primary, not tectonic. As outlined in Figure 18, 3 main contact types are present between the River Valley intrusion and other rock units in the map area:

1. preserved intrusive contacts;
2. deformed and disrupted intrusive contacts, and
3. wholly tectonic (fault) contacts.

Near the northwest edge of Dana Township, the western contact of the intrusion is tectonic, as originally described by Davidson (1986). The northern and eastern contacts of the intrusion in this area, however, are primary, although they are locally cut, with minimal lateral offset, by mylonites of the Southern-Grenville boundary zone. Mineralization in northwestern Dana Township (Dana North and South zones of Pacific North West Capital Corporation) is spatially associated with preserved intrusive contacts. Much of the northern contact of the intrusion in Dana Township is likely primary, and both the Lismer's Ridge and Azen Creek zones occur near this contact. It should be noted that the Azen Creek zone is located near, but not at the contact. In Crerar Township, a primary intrusive contact is preserved in the area that includes the Tomrose occurrence, and Crerar 2 to 4 (*see* Figure 18). To date, most of the mineralization identified in Crerar Township lies near this contact.

In contrast, most of the southern contact of the intrusion in Crerar Township, although poorly exposed, is a major shear zone, which is discordant to internal contacts in the intrusion. It is likely that the eastern contact of the River Valley intrusion north of the Sturgeon River, is also a tectonic contact.

Examples of tectonized intrusive contacts may be present in 3 areas. The western contact of the intrusion along Highway 805, particularly in the southern half of Dana Township, is of this type. However, it is possible that this contact represents an upper, rather than a basal, contact of the intrusion. The other two examples occur in Crerar Township, but represent areas where zones of mafic straight gneisses are in contact with other highly deformed gneisses or different units within the intrusion. Mineralization present at Crerar 5, 6 and 7 is related to one of these contacts. This mineralization occurs both along layers within the gneisses, and along the margins of boudinaged quartz and quartz-feldspar-mica veins in the gneisses. It is speculated that these rocks may represent a highly deformed equivalent of the rocks present at the Tomrose occurrence. Similar rocks occur just south of Glen Afton, south of the Sturgeon River, however, to date no mineralization has been reported from this area.

Hrominchuk (1999, 2000) recognized two types of mafic rock associations near areas of primary contacts. These are a marginal zone and an inclusion-bearing zone. There is considerable variation in thickness of both these zones along the primary contacts of the intrusion, ranging from 50 m thick to almost 500 m thick in the Dana North area. Figure 18 also attempts to show the relative thickness of these units near the contacts. To date, mineralized zones along the contact occur where these units are relatively thick (e.g., Dana North, Varley, Azen, Tomrose).

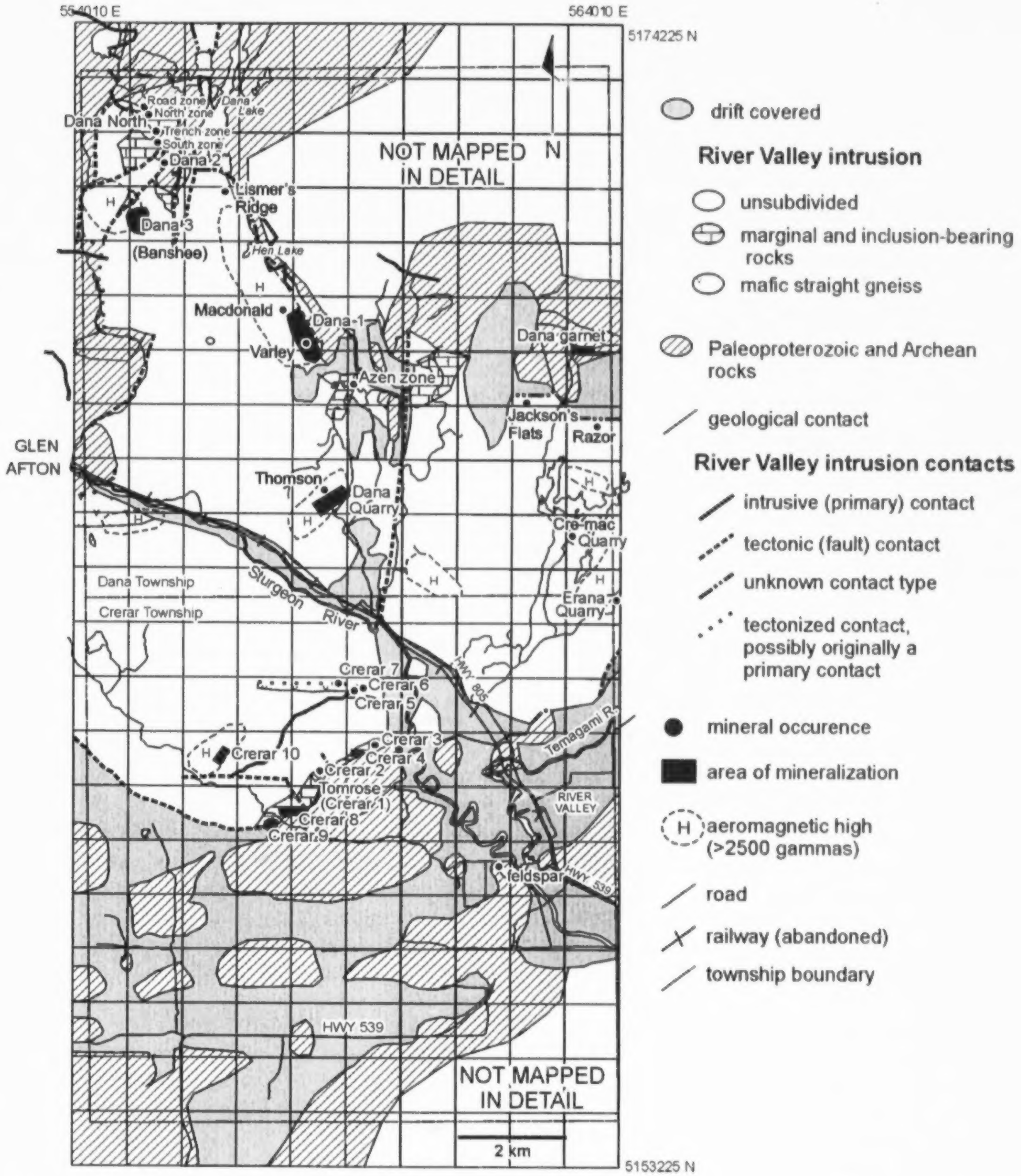

554010 E
564010 E
5174225 N
5153225 N
N
NOT MAPPED IN DETAIL
NOT MAPPED IN DETAIL
2 km
Road zone
North zone
Trench zone
South zone
Dana Lake
Dana North
Dana 2
Lismer's Ridge
Dana 3
(Banshee)
Hen Lake
H
Macdonald
Dana-1
Varley
Azen zone
Dana garnet
Jackson's Flats
Razor
GLEN AFTON
Thomson
Dana Quarry
Cre-mac Quarry
Erana Quarry
Dana Township
Crerar Township
Sturgeon River
HWY 805
Crerar 7
Crerar 6
Crerar 5
Crerar 10
Crerar 3
Crerar 4
Crerar 2
Tomrose (Crerar 1)
Crerar 8
Crerar 9
Temagami R.
RIVER VALLEY
feldspar
HWY 539
HWY 539
drift covered
River Valley intrusion
unsubdivided
marginal and inclusion-bearing rocks
mafic straight gneiss
Paleoproterozoic and Archean rocks
geological contact
River Valley intrusion contacts
intrusive (primary) contact
tectonic (fault) contact
unknown contact type
tectonized contact, possibly originally a primary contact
mineral occurence
area of mineralization
H aeromagnetic high (>2500 gammas)
road
railway (abandoned)
township boundary

Figure 18. Map showing the location of metallic and industrial mineral occurrences within the map area, as well as the various contact types identified along the margin of the River Valley intrusion in Dana and Crerar townships. See text for discussion of contact types.

Stratigraphy and Petrography

Although historically referred to as an anorthosite to anorthositic gabbro intrusion, the River Valley intrusion is dominated (~60% of surface area) by gabbro, norite, gabbronorite, leucogabbronorite and leuconorite, with some units containing modal olivine. True anorthosite makes up less than 10% of the surface area of the intrusion, but even in these areas, the distribution of mafic minerals is irregular, so that the areas of anorthositic rock are closer to noritic anorthosite or gabbroic anorthosite in composition. Noritic and gabbroic anorthosite probably underlie about 30% of the surface area of the intrusion. Observed stratigraphy in the intrusion differs north and south of the Sturgeon River.

NORTH OF THE STURGEON RIVER

Low regional dip of the layers, and poor exposure in key areas in Dana Township have hampered stratigraphic analysis, despite the textural and mineralogical preservation of the rocks. Despite these difficulties, Hrominchuk (2000), as presented in Figure 13, developed an interpretive stratigraphic section for the River Valley intrusion located north of the Sturgeon River. The intrusion north of the Sturgeon River has been subdivided into five zones (Hrominchuk 2000; James et al. 2002a), as follows:

1. a Marginal Zone
2. an Inclusion and/or Fragment-bearing Zone
3. a layered Olivine Gabbronorite Zone
4. a Layered Gabbronorite Zone, and
5. a massive, locally varitextured, Leucogabbronorite Zone.

Marginal Zone

The Marginal zone is characterized by a fine- to medium-grained, black plagioclase-phyric, quartz-phenocryst-bearing, gabbronorite that is partly chilled and is typically strongly mineralized at the contact with granitic plutonic and gneissic rocks. This contact is commonly sheared and normally consists of a complex chaotic mixture of footwall blocks and fine- to medium-grained gabbronoritic rocks. Because rocks immediately adjacent to the contact usually contain large blocks and screens of footwall material, exact definition of the contact in some areas is problematic. The Marginal zone consists mostly of medium-grained norite to gabbronorite and is typically well preserved. In thin section, the rock consists of dark-brown to tan-colored cumulate (An_{79} core; An_{74} rim) to intercumulate (An_{68}) plagioclase, woody-brown cumulate orthopyroxene (En_{44-76}), interstitial clinopyroxene, with accessory magnetite, quartz, biotite, sulphides, and calcic myrmekite. Fragments are commonly quartzofeldspathic gneiss, alkali-feldspar granite and amphibolite gneiss. Granitic fragments contain quartz with a small amount of alkali feldspar and biotite or amphibole. Quartzofeldspathic gneiss fragments commonly have a preserved gneissic texture and are mostly quartz with a small amount of biotite. Amphibolite gneiss fragments are a fine-grained, commonly foliated, matte of blue-green amphibole and epidote group minerals. Where metamorphosed, the Marginal zone norite and gabbronorite normally contain fine-grained acicular amphibole (actinolite); plagioclase is white to clear and shows zoisite alteration. Other metamorphic phases include garnet, hornblende and biotite.

Inclusion and/or Fragment-Bearing Zone

This zone is commonly in gradational contact with the underlying Marginal zone, but its appearance is marked by a sharp increase in the size and amount of felsic fragments and the appearance of compositionally and texturally varied mafic to ultramafic inclusions or xenoliths. Inclusions are of three main types, alkali feldspar granite and other granitic rocks, amphibolite, and olivine-rich rocks (troctolites, peridotites). Granitic, gneissic and amphibolite fragments are similar to those described above for the Marginal zone. They are commonly surrounded by pods or lenses of a very coarse-grained to pegmatitic assemblage of biotite, muscovite, amphibole, plagioclase, quartz and alkali feldspar. Autoliths are abundant (typically 10 to 30%) and locally (e.g., outcrop scale) may constitute up to 100% of the rock. Troctolite or peridotite autoliths are similar in all respects to the olivine norite to melatroctolite and peridotite from the Olivine Gabbronorite zone described below; most are olivine-bearing gabbronorite to peridotite in composition, with subordinate leucogabbronorite. They are usually well rounded and weakly to very strongly mineralized. The host matrix to the autoliths and fragments is typically a fine- to medium-grained, green to black gabbro or olivine-bearing gabbro to gabbronorite, often with disseminated to blebby sulphides.

Olivine Gabbronorite Zone

It is composed of 0.3 to 1.5 m thick layers that are olivine-rich at the base, and erosive into underlying layers, and which grade upward into olivine gabbronorite or troctolite to slightly more plagioclase-rich end members. Layers are deeply weathered due to the presence of serpentine minerals and fine-grained magnetite after olivine. This zone is well exposed in only a few places, but is normally 50 to 150 m thick, and grades into the overlying, olivine-poor layered Gabbronorite zone. The Olivine Gabbronorite zone contains a wide range of rock types, however, olivine is present in most, with troctolite and olivine norite predominant. Olivine is generally medium- to coarse-grained, Mg-rich (Fo_{72-76}), coronitic, and variably serpentinized. Plagioclase is calcic (An_{72-76}), dark-colored, and inclusion-rich. Orthopyroxene (En_{70-76}) occurs in two forms, as euhedral woody prisms, and as large (up to 10 cm) oikocrysts enclosing olivine and plagioclase. Clinopyroxene is found only as interstitial anhedral crystals.

Gabbronorite Zone

The Gabbronorite zone is composed of metre-scale, modally layered rocks with a maximum continuous thickness of about 200 m. This represents a minimum stratigraphic thickness, since the top of the section is always truncated by faults or zones of intense deformation. It typically consists of alternating metre-thick layers of norite and gabbronorite (±olivine) and leucogabbronorite. Locally, this unit is very coarse-grained, with zones rich in felsic fragments surrounded by pegmatitic pods containing quartz, epidote, magnetite, alkali feldspar, plagioclase, amphibole, pyroxene, biotite and garnet. The Gabbronorite zone consists of layers that begin as olivine-bearing norite and fractionate to gabbronorite. Coarse-grained black norite dominates; it consists of large (2 cm) orthopyroxene (En_{57-66}) and brown plagioclase (up to 3cm) (An_{58-75}) primocrysts, interstitial clinopyroxene and inverted pigeonite, and rare olivine. Metamorphosed equivalents contain altered plagioclase, amphiboles (fine-grained actinolite and coarse-grained hornblende), small garnets and quartz.

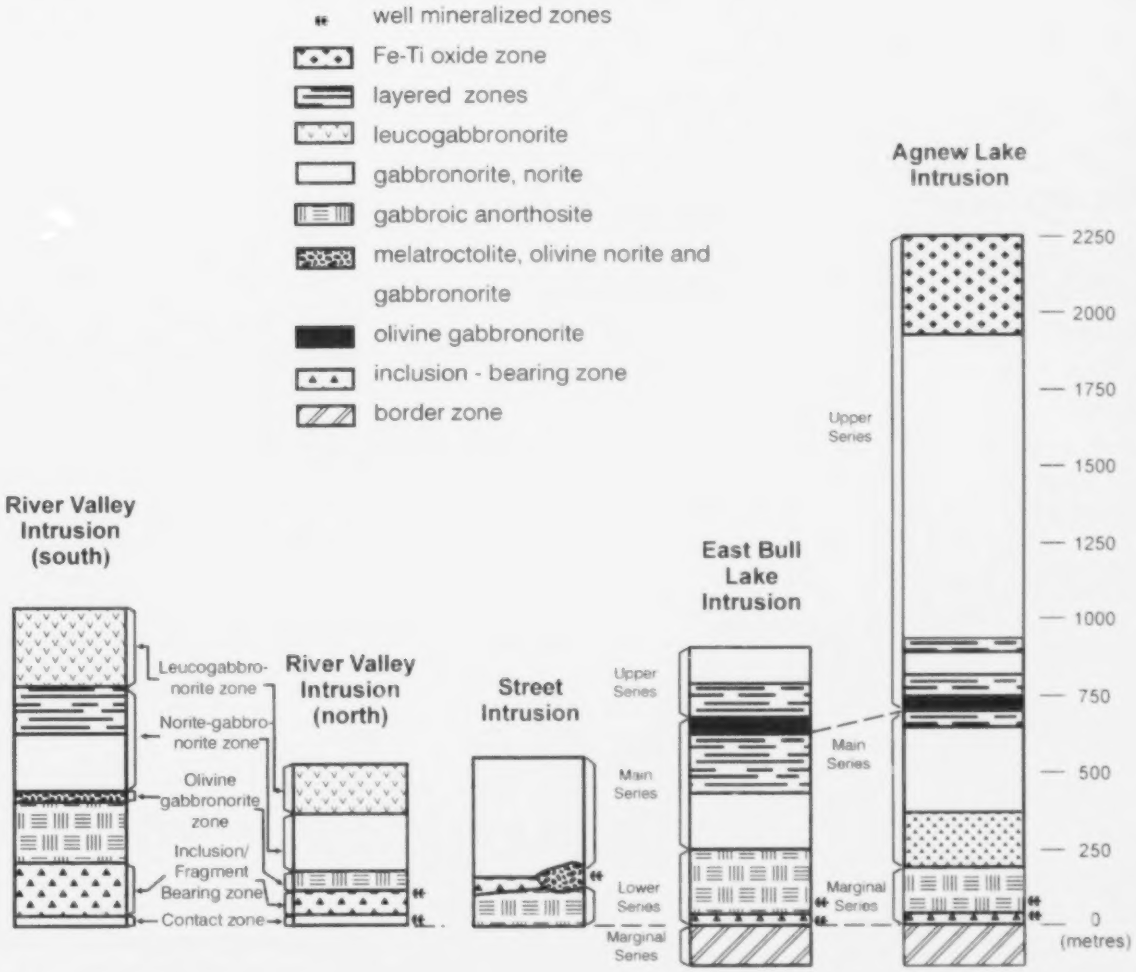
Leucogabbronorite Zone

This zone consists of non-layered, massive, medium- to coarse-grained rocks ranging in composition from leucogabbronorite to anorthosite. It forms the highest stratigraphic levels of the intrusion (generally the tops of topographic highs) in Dana Township. They are commonly highly deformed or faulted; a complete section of these rocks has not yet been found in Dana Township, however, a more complete section may be present in Crerar Township (Easton and Hrominchuk 1999). These rocks consist mainly of dark plagioclase (An_{56-63}) with subordinate interstitial and primocryst clinopyroxene and inverted pigeonite (En_{56-69}). Where metamorphosed, the more leucocratic rocks form very white-weathering rocks with small pods of amphibole-rich material dispersed throughout.

SOUTH OF THE STURGEON RIVER

As previously noted, establishing a stratigraphic column for the River Valley intrusion has been difficult, despite the state of preservation of the rocks. South of the Sturgeon River, steeper regional dips have made the task somewhat easier, however, the section there may contain more layer-parallel faulting, and units are only well preserved in the southwestern part of the intrusion. Easton and Hrominchuk (1999) originally suggested that a section up to 3.5 km thick could be identified, however, this interpretation assumed that the units were dipping uniformly to the west at roughly 50°, that the section was not folded, and that there were no layer-parallel faults present. Further analysis indicated that the section was indeed folded (Easton and Hrominchuk 2001a). Unlike the area north of the Sturgeon River, this section has not been formally divided into stratigraphic zones; for reference, however, informal zone names are given in italics to facilitate comparison with the Dana Township section. The Crerar Township section has a maximum thickness of 1.4 km, and from base upward, consists of:

- 150-200 m of gabbro and melanogabbro, forming a heterogeneous ***Marginal zone*** that contains fragment-rich zones, disrupted layering, and considerable diking. Sulphides are common in this zone. This zone grades upward into leucogabbro and anorthositic gabbro. This zone corresponds roughly to the Marginal and Inclusion and/or Fragment-bearing zones present in the intrusion north of the Sturgeon River.
- 400-500 m of gabbroic anorthosite to anorthosite (***Anorthosite zone*** and thin ***Olivine Gabbronorite zone***). Melanogabbro and olivine melanogabbronorite layers up to 2 m thick occur near the top of this zone. This zone apparently does not have an equivalent unit north of the Sturgeon River, but a lowermost gabbroic anorthosite to anorthosite is present in most other East Bull Lake suite intrusions (Figure 19). It is possible that the melanocratic layers in the upper part of this zone correspond to the Olivine Gabbronorite zone present north of the Sturgeon River.
- 350 m of norite and gabbronorite (***Gabbronorite zone***), commonly layered on the scale of centimetres to decametres, with layers having pyroxenite bases and gabbroic anorthosite tops (*see* Photo 24b). Layering on the scale of metres to decametres is also inferred to be present in this zone. This zone may be equivalent to the Gabbronorite Zone present north of the Sturgeon River.
- 200 m of leucogabbro to gabbroic anorthosite (***Leucogabbronorite zone***). This zone may be equivalent to the Leucogabbronorite Zone present north of the Sturgeon River.
- 200 m or more of oxide-bearing leucogabbro to gabbroic anorthosite (***Oxide-bearing Leucogabbronorite zone***). A regional magnetic anomaly is associated with this unit. Rocks within this zone show a marked decrease in Mg-number (less than 50) compared to other stratigraphic units in the River Valley intrusion (typically greater than 57).
- The top of the section is not observed, due to intense deformation in the rocks above this stratigraphic level.



well mineralized zones
Fe-Ti oxide zone
layered zones
leucogabbronorite
gabbronorite, norite
gabbroic anorthosite
melatroctolite, olivine norite and gabbronorite
olivine gabbronorite
inclusion - bearing zone
border zone
River Valley Intrusion (south)
Leucogabbro-norite zone
Norite-gabbro-norite zone
Olivine gabbronorite zone
Inclusion/ Fragment Bearing zone
Contact zone
River Valley Intrusion (north)
Street Intrusion
East Bull Lake Intrusion
Upper Series
Main Series
Lower Series
Marginal Series
Agnew Lake Intrusion
Upper Series
Main Series
Marginal Series
2250
2000
1750
1500
1250
1000
750
500
250
0
(metres)

Figure 19. Generalized cross-sections for the Street metagabbro and the River Valley, East Bull Lake and Agnew Lake intrusions of the East Bull Lake intrusive suite. East Bull Lake section modified from Peck et al. (1995), Agnew Lake intrusion section modified from Vogel (1996), River Valley data from this study and James et al. (2002a).

The most significant difference between the Dana (River Valley intrusion (north) in Figure 19) and Crerar (River Valley intrusion (south) in Figure 19) townships sections is the presence of a thick unit of leucogabbro to anorthosite between the Marginal zone and the Olivine Gabbronorite and Gabbronorite zones in the Crerar Township section. In one locality, a few outcrops of nodular anorthosite are present near the base of the leucogabbro to anorthosite unit. At another locality, this unit contains a decametre-thick layer of megacrystic anorthosite, with 1 to 5 cm equant, blocky plagioclase crystals partly separated by clotty, coarse-grained and weakly poikilitic, amphibolitized pyroxene. In addition, the varitextured to massive uppermost Oxide-bearing Leucogabbronorite zone is not observed in Dana Township, and is the only unit which contains both Mg-number and normative An contents <55.

STRATIGRAPHIC COMPARISON WITH OTHER EAST BULL LAKE SUITE INTRUSIONS

As shown in Figure 19, the composite stratigraphic section from the best preserved enclave of the River Valley intrusion in Crerar Township contains elements common to both the northern River Valley, the East Bull Lake, and the Agnew Lake intrusions. If the Crerar Township stratigraphy is a true section through the intrusion, then it is similar in thickness to other East Bull Lake intrusions (*see* Appendix 4). The exception is the Agnew Lake intrusion (~2.3 km), which unlike the other intrusions, includes felsic differentiates near the top. The Crerar Township section also suggests that the River Valley intrusion locally includes an anorthositic zone near the base of the body, similar to most other East Bull Lake intrusions (*see* Figure 19).

Geochemistry

Geochemical results from the intrusion are summarized in Appendix 3 and Figures 5d, 5e, 5f and 14. Overall, the chemistry of the rocks is similar to that of other East Bull Lake suite intrusions. Silica is generally less than 50 weight percent (*see* Appendix 3). Vogel et al. (1999) noted that in the case of the Agnew Lake intrusion, SiO_2 less than 50 weight percent is characteristic of the stratigraphically lower part of the intrusion. The same effect may be present in the River Valley intrusion, as most of the samples reported to date are from the lower part of the intrusion (below the Oxide-Bearing Leucogabbronorite zone). A few samples, located stratigraphically higher in the River Valley intrusion in Crerar Township show a marked decrease in Mg-number (from typically greater than 57 to less than 43). These rocks are generally of gabbroic anorthosite composition and oxide-bearing. Vogel et al. (1999) document a similar decrease in Mg-number in the upper series of the Agnew Lake intrusion, suggesting that it may be possible to use geochemically derived Mg-numbers and An contents to assist in stratigraphic correlation within the River Valley intrusion.

Representative analyses of each stratigraphic unit present in the River Valley intrusion north of the Sturgeon River are listed in Appendix 3, as well as in Hrominchuk (2000) and James et al. (2002a). Rocks of the Marginal zone are CIPW quartz-normative; Olivine Gabbronorite zone rocks are olivine-normative, whereas most rocks in the upper units are only silica-saturated. Samples from the Marginal zone (samples CZ7-500, CZ7-1000 and 99RME-2291, Appendix 3) show much higher Ti, Fe, K, Na, P, Ba, Zr and Y contents than do most other River Valley intrusion samples (samples 99RME-0388, 99RME-0505, 99RME-2116, 99RME-2242, 99RME-2243, 99RME-2244, 99RME-2371A, Appendix 3). These elemental variations were interpreted by Hrominchuk (2000) as a possible contamination signature. Although Ti and Fe might not normally be considered indicative of wall rock contamination, the high concentration of these elements in some footwall phases (sample 99RME-0375, Appendix 2), relative to typical River Valley intrusion rocks, is consistent with some of the Ti and Fe contents in sample CZ7-1000 resulting from wall rock assimilation (James et al. 2002a).

The matrix of the Inclusion and/or Fragment-Bearing zone (sample 99RME-2243, Appendix 3) is high in Mg, Ca, Al and Fe, consistent with its plagioclase, orthopyroxene and olivine-dominated mineralogy. The fragments, inclusions and xenoliths of this zone are extremely varied in composition, partially resorbed, and commonly mineralized; felsic fragments show similarities to the footwall alkali feldspar granite (James et al. 2002a). Mafic inclusions (sample 99RME-2242, Appendix 3) are similar to the rocks in the lowest part of the layered Olivine Gabbronorite zone. The Olivine Gabbronorite zone is characterized by rocks high in MgO (15 to 24 wt. %) and low in SiO_2 (38 to 45 wt. %), with anomalous Ni contents attributed to the predominance of primocryst olivine (samples JLHS1-S3 and 99RME-0516, Appendix 3). Rocks from the layered Gabbronorite zone show gradual fractionation to more Si-, Al-, Ca-, Na-, K-rich and Mg-poor compositions (samples JLHS2-S1 and JLHS2-S4, Appendix 3), a trend also observed in the uppermost stratigraphic unit (samples 99RME-2116 and 99RME-2244, Appendix 3). A sample of magnetite gabbro from the uppermost part of the stratigraphy in Crerar Township (sample 99RME-0505, Appendix 3) may be similar to the lowermost ferrogabbros from the Agnew Lake intrusion, and is the most evolved sample found to date in the River Valley intrusion.

Pearce element ratio diagrams for the River Valley intrusion published in James et al. (2002a) and detailed petrography indicate major and trace element trends within the intrusion are controlled by plagioclase, olivine and orthopyroxene, with very little contribution from clinopyroxene (James et al. 2002a). Samples from the Olivine Gabbronorite zone show a variation from olivine + plagioclase to plagioclase + orthopyroxene controlled geochemistry with height (James et al. 2002a). Plagioclase is commonly a phenocryst phase within marginal and fine-grained rocks indicating very early crystallization, most likely quickly joined by olivine as the first cumulate phases. During crystallization of the marginal rocks and the Olivine Gabbronorite zone, fractionation and cooling of the magma caused orthopyroxene to replace olivine as a cumulate phase. This is indicated by orthopyroxene rims on olivine and large orthopyroxene oikocrysts enclosing olivine and plagioclase near the top of this zone (James et al. 2002a). Rocks above this point show trends indicating fractionation of the magma due to plagioclase and orthopyroxene toward more Fe- and alkali-rich compositions.

Chondrite-normalized rare earth element patterns for samples north and south of the Sturgeon River are show in Figures 14 and 5f, respectively. Most samples show total rare earth element contents and patterns similar to those found in the East Bull Lake and the Agnew Lake intrusions. In Figure 14, rare earth element patterns for the proposed Dana Township stratigraphy show a slight fractionation trend with stratigraphic height and the influence of cumulate plagioclase (reflected in the magnitude of the negative Eu anomaly). The contaminated contact sample shows significant light rare earth element enrichment over other marginal samples and rocks of all other zones. Figure 5f shows that there are two groups of melanocratic rocks. One with patterns and rare earth element contents similar to other River Valley intrusion rocks; the other with high total REE and La/Yb. This second group has higher normative-orthopyroxene and lower-normative olivine contents than the first. Interestingly, a similar two-fold grouping is present in the orthopyroxene hornblendite samples (*see* Figure 5f), perhaps suggesting a genetic linkage between the River Valley intrusion and these bodies.

A sample of a primitive dike or layer from the Marginal zone (sample 99RME-2291, Appendix 3) exhibits a flat (~10 times chondrite) to slightly U-shaped pattern (*see* Figure 14), and is also characterized by relatively high silica and MgO, and low Ti and alkalis. It may represent a boninite-like parent magma composition for the River Valley intrusion (James et al. 2002a). The significance of such a parental magma has already been discussed in the section "Magma Composition and its Relationship to Mineralization".

Economic Geology

METALLIC MINERALS

Assay Results

Assay results are compiled in Appendix 5, and include data for both country rocks (in order to establish regional background levels), dike rocks, rocks from the River Valley intrusion, as well as grab samples from historic trenches. Location data for all samples is provided in Appendix 5; Figure 18 shows the general location of historic occurrences and new areas of mineralization. Most of the assay data listed herein was first reported in Easton and Hrominchuk (1999), during the early stages of active exploration on the River Valley intrusion. Assay samples from the River Valley intrusion include rocks containing varied amounts of visible sulphide minerals, as well as sulphide-poor rocks collected for the purpose of geochemical characterization of units. Assay data are displayed in Figure 20a, a log plot of Pd versus Cu; Figure 20b, a plot of Ni versus Mg-number; Figure 20c, a ternary plot showing total Pt-Pd-Au, Cu and Ti; and Figure 20d, a plot of Cu versus total Pt+Pd+Au. In this report, samples containing between 2- and 4-times background levels of Cu and/or combined Pt+Pd+Au are described as anomalous (i.e., between 70 to 140 ppm and 70 to 140 ppb, respectively). Samples containing higher levels (i.e., greater than 140 ppm and 140 ppb, respectively) are described as highly anomalous.

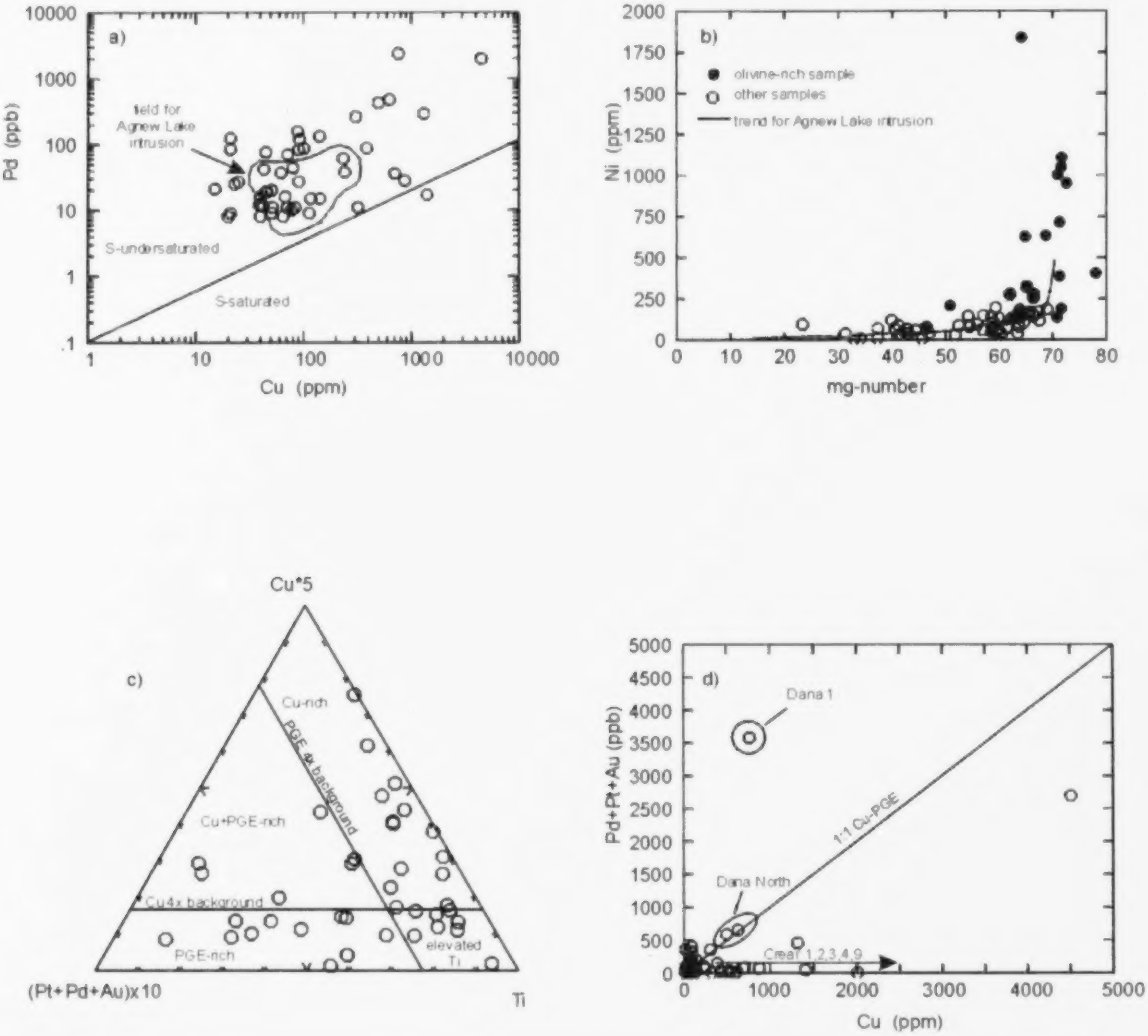


Figure 20. a) Plot of log Pd (ppb) *versus* log Cu (ppm) for non-mineralized samples from the River Valley intrusion, Dana-Crerar area. Field of Agnew Lake intrusion samples and boundary between S-saturated and S-undersaturated field *from* Vogel et al. (1999). **b)** Plot of Ni *versus* Mg-number for non-mineralized samples from the River Valley intrusion. The plot also shows data from a River Valley intrusion in Street Township. **c)** Plot of Pd+Pt+Au *versus* Cu *versus* Ti for mineralized and non-mineralized samples from the River Valley intrusion, Dana-Crerar area. **d)** Plot of Cu (ppm) *versus* combined Pd+Pt+Au (ppb) for samples from the River Valley intrusion, Dana-Crerar area.

In 1999, field party personnel discovered 3 new areas of mineralization within Dana Township on ground staked by Pacific North West Capital Corporation, and 2 in Crerar Township on ground staked by Mustang Minerals Corporation (*see* Figure 18), both of which have been subsequently examined by industry geologists. In none of these areas, was there evidence of prospecting prior to our sampling. The most significant of the new mineralized areas (Dana 1) is located about 1.5 km northeast of the Azen Creek zone, and contains 3583 ppb combined Pd-Pt-Au, and 769 ppm Cu (sample 99RME-2087, Appendix 5). An area at least 300 m long and 50 m wide of sulphide-bearing rocks is found in the vicinity of this sample. This area is now referred to as the Varley zone by Pacific North West Capital Corporation.

The second mineralized area (Dana 2) occurs south of Dana Lake, roughly 400 m southeast of the South Zone of the Dana North property. This sample contains 3729 ppm Cu, from a rock that contained only a minor amount of visible sulphide minerals. It is located within gabbro of the marginal zone of the intrusion, however, this sample comes from a large, preserved lozenge within an extensive mylonite zone present within the Southern-Grenville province boundary zone, and thus the continuity of this mineralization to the southeast needs to be established. The Dana 3 zone encompasses a 1 km^2 area located 1.5 km south of the Dana North property. Five samples were collected from gabbroic anorthosite from this zone, all containing visible sulphide minerals. Two samples (Appendix 5) contain Cu at levels greater than 4 times background, 323 and 874 ppm. The other 3 samples contain anomalous levels of Cu, but more significantly, these samples are highly anomalous in PGE (Appendix 5). This was the first indication that gabbroic anorthosite units from the River Valley intrusion contained anomalous PGE values, although it was not unexpected, given previous results obtained from compositionally equivalent rocks in Street Township (Easton 1999). Pacific North West Capital Corporation now calls this the Banshee zone.

Crerar 4 lies roughly 500 m west of a trench that was excavated in the mid-60s (Appendix 5, samples 99RME-0576 and 99RME-0577). These samples occur in a thick segment of the inclusion- and/or fragment-bearing unit present in the marginal zone of the intrusion in this area. Although the samples are highly anomalous for Cu, they are not anomalous for PGE (Appendix 5). In this regard, they are similar to the majority of the Crerar samples, which show anomalous to highly anomalous values for Cu, but contain low or trace concentrations of PGE. The only highly anomalous PGE values come from the Tomrose showing (Appendix 5). Anomalous Cu values were found in samples located southeast of the forest access road in Crerar Township (Crerar 9), roughly 1 km southeast of the Tomrose showing (samples 99RME-0542, 99RME-0544, 99RME-0545, Appendix 5). Results from Crerar 10 are noteworthy, as they are anomalous in PGE. These samples occur in a magnetite-rich leucogabbronorite.

Platinum/palladium (Pt/Pd) ratios show considerable variation in the intrusion (Appendix 5). Ratios are close to 1.0 at above background and anomalous levels, but are 0.3-0.4 in highly anomalous samples. The significance of this is not clear, but must be related to the process(es) that resulted in concentration of the PGE in the mineralized zones with the highest PGE contents.

Keays (1995) has suggested that the presence of a sulphur-undersaturated magma is a requirement for the formation of major Cu-Ni-PGE deposits. Figure 20a shows that non-mineralized and mineralized samples from the River Valley intrusion are sulphur-undersaturated, indicating that this requirement has been satisfied in the case of the River Valley intrusion.

Vogel et al. (1999) noted that for the Agnew Lake intrusion, there was a positive correlation between Ni and Mg-number, suggesting that Ni partitioned into olivine phenocrysts during magmatic differentiation and that the sulphide minerals were not important during magmatic crystallization. Based on the limited data present so far for the River Valley intrusion, it would appear that a positive correlation between Ni versus Mg-number may not be present in all units present in the River Valley intrusion (*see*

Figure 20b). The highest Ni values in any of the analyzed samples (629-714 ppm) occur in olivine-bearing melanocratic rocks which have normative olivine contents of greater than 12. There does, however, appear to be a positive correlation between Ni and Co and normative olivine, rather than the expected association of Ni and Cr. The Ni-Co association occurs in rocks having high normative orthopyroxene contents, with orthopyroxene as the primary pyroxene species, and it is possible Co may be substituting for Fe or Mg in orthopyroxene. The absence of a Ni-Cr association in olivine-bearing and olivine-normative samples may indicate the removal of Cr at an early stage during the magmatic evolution of the intrusion. Early removal of Cr is consistent with the presence of Cr-enriched, ~ 2468 Ma orthopyroxene hornblendite bodies in the region. There is no clear correlation between Ni and Cu content in mineralized samples. The highest assayed sample contains 519 ppm Ni, most contain less than 300 ppm Ni, lower than the Ni contents present in non-mineralized olivine-bearing samples. Consequently, in the absence of a measure of olivine content in the mineralized samples, it is not possible to distinguish between Ni in sulphides and Ni in olivine in the samples. This makes it difficult in determining a consistent, reliable, background level for nickel in the River Valley intrusion.

In the field, a common association was noted between the presence of oxide minerals and sulphides. Both Cr and Ti data were collected in the assays, to see if there was a relationship between specific oxide compositions and sulphide mineralization. Neither element has a systematic relationship with Cu-rich sulphides (*see* Figure 20c). This likely reflects the fact that magnetite may be the dominant oxide phase in the intrusion, with chromite and ilmenite being minor oxide phases.

Although it has been suggested for the River Valley intrusion that high PGE values are typically associated with chalcopyrite-rich samples, data from this study indicates that this is not always the case (*see* Figure 20d). Some of the highest PGE values (e.g., sample 99RME-2087, Appendix 5) come from samples containing anomalous, not highly anomalous, Cu contents. In addition, in the vicinity of the Tomrose occurrence, highly anomalous Cu values do not correspond to areas of highly anomalous PGE (*see* Figure 20d). This suggests that, for prospecting purposes, systematic sampling of rock units may be a safer sampling strategy than focussing solely on rocks showing rust stains or visible sulphide minerals.

Dana North

Promising platinum-group element assay values from rocks of the River Valley intrusion near Dana Lake and Azen Creek were first reported by prospectors L. Luhta, R. Bailey and R. Orchard in November 1998 (Photos 29a, 29b). Subsequently, Pacific North West Capital Corporation staked most of the northern contact of the River Valley intrusion in Dana Township, with Mustang Minerals Corporation staking most of the River Valley intrusion in Crerar township, as well as part of the northern contact near the Dana-McWilliams townships boundary. As illustrated in Figure 18, Pacific North West Capital has identified a dozen targets along this northern contact. These are, from northwest to southeast, the Pardo, Dana North, Dana South, Banshee, Lismer's Ridge (Lismer's North and Lismer's South), Macdonald, Varley, Azen, Jackson's Flats, and Razor zones. The Thomson zone is located more centrally in the intrusion. The Dana North property of Mustang Minerals Corporation is located roughly 500 m east of the Razor zone.

Between 2000 and spring 2003, Pacific North West Capital Corporation, in conjunction with their partner, Anglo American Platinum Corporation Limited, completed 5 diamond drilling programs. Approximately 288 diamond-drill holes totalling 58 000 m have been completed on their River Valley intrusion property in Dana Township. Diamond drilling was focussed almost entirely on the Dana North and Lismer's Ridge targets (*see* Appendix 1 for summary). A 6th diamond drill program, aiming for a potential total of another 40 000 m of drill core, is underway, also focussing mainly on the Dana North and Lismer's Ridge zones (press release, Pacific North West Capital Corporation, April 10, 2003; http://www.pfncapital.com/s/NewsReleases). The scope of these drilling programs is too large to effectively summarize in this report, consequently, the reader is referred to the comprehensive assessment file reports related to these drilling programs, as summarized in Appendix 1 under Dana Township.

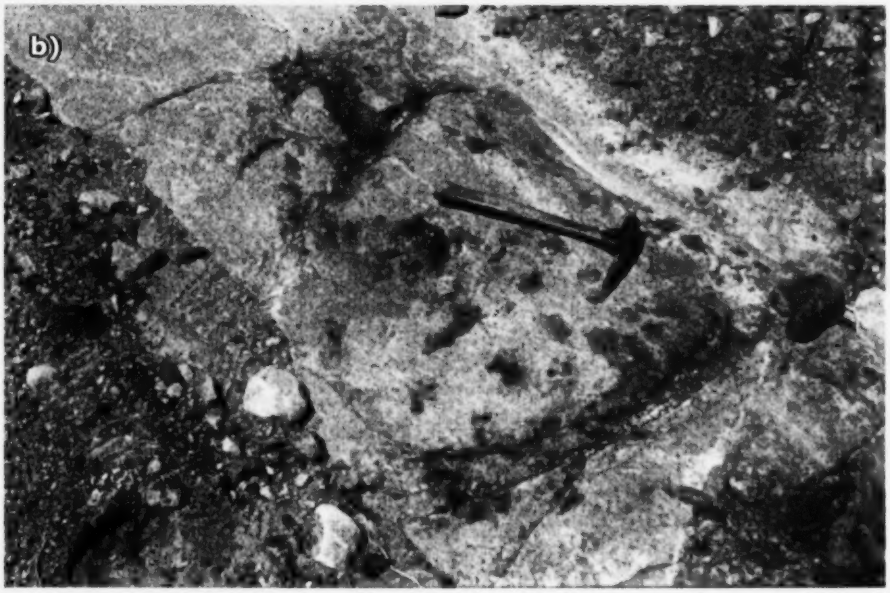


Photo 29. a) Azen Creek zone in November 1998, after initial stripping and reporting of anomalous platinum group element contents. From left to right, R. Orchard, L. Lutha and R. Bailey. Dana Township. Station 98RME-0354. UTM 558955E 5167590N. **b)** Azen Creek zone in September 1999, after additional stripping of the outcrop. Dana Township. Note rusty patches reflecting concentrations of sulphides and platinum group metals, as well as dark inclusions in fine-grained, lighter coloured, gabbronorite matrix. Hammer handle is 30 cm long. UTM 558955E 5167590N.

Pacific North West Capital Corporation has released 2 mineral resource estimates for the Dana North zone, based on the Phase 1 to 5 drilling programs. In both cases, the resource studies were done by Derry, Michener, Booth and Wahl Consultants Limited. The first in-situ resource estimate, issued on October 16, 2001 (Press Release, Pacific North West Capital Corporation, October 16, 2001), estimated a total measured, identified and inferred resource of 593 000 ounces palladium, platinum and gold at Dana North, Dana South and Lismer's Ridge. This estimate used a 0.7 g/tonne Pt+Pd cut-off grade, and can also be expressed as 12.7 million tonnes at 1.46 g/t Pt+Pd+Au. This can be broken down into 7.74 million tonnes at 1.60 g/t Pt+Pd+Au at Dana North and South, and 4.97 million tonnes at 1.24 g/t Pt+Pd+Au at Lismer's Ridge.

The second mineral resource estimate, issued on October 17, 2002 (Press Release, Pacific North West Capital Corporation, October 17, 2002), estimated total measured and indicated resource of 825 900 ounces palladium, platinum and gold. In addition, there were inferred resources of 200 600 ounces palladium, platinum and gold, yielding a total of 1 026 500 ounces at Dana North and Lismer's Ridge. This estimate used a 0.7 g/tonne Pt+Pd cut-off grade, and can also be expressed as 18.1 million tonnes of measured and indicated at 1.36 g/t Pt+Pd and 5.4 million tonnes inferred at 1.11 g/t Pt+Pd. Roughly 60% of this resource is in the Dana North area.

A description of the Dana North zone has been published by S. Jobin-Bevans, the Vice-President of Exploration for Pacific North West Capital Corporation in James et al. (2002b). The subsequent description, shown below in a slightly smaller font, is adapted from that published report.

The distribution of the marginal Inclusion-bearing/Breccia zone (roughly equivalent to the Inclusion- and/or Fragment-bearing zone of Hrominchuk (2000) and James et al. (2002a)), the loci of mineralization, is in abrupt, intrusive contact to the east with the Neoarchean-age Pardo gneiss, and to the west these zones are replaced by a weakly layered to massive leucogabbro-gabbro-melagabbro sequence. Small pod-like, alkalic intrusions of unknown age are observed at two places along the intrusive contact where they displace the Inclusion-bearing/Breccia Zone. As well, faults related to the Grenville Front and a 1238 Ma Sudbury swarm olivine-magnetite gabbro dyke cut or displace this zone. Silicate assemblages that host the mineralization in this part of the River Valley intrusion exhibit upper greenschist facies mineralogy in contrast to the upper amphibolite facies and preserved magmatic assemblages that dominate the remainder of the intrusion. The stratigraphy of the Inclusion-bearing/Breccia Zone is normally ~100 m wide in plan view. From the footwall Pardo gneiss, westward into the intrusion, the sequence and character of the distinguishable units are:

1. *Footwall Breccia unit:* typically 5 to 15 m wide, but may be absent. It consists of partly rounded to angular, centimetre- to decimetre-size fragments of country rock (~75%; Pardo gneiss, Archean gabbro, diabase, diorite, minor Huronian Supergroup metasedimentary rocks) and River Valley intrusion material (~25%; chilled gabbro and medium-grained melagabbro) in a matrix of finer grained rock of similar composition and (or) an aplitic to granitic matrix. A narrow zone of migmatite at the contact of the intrusion is probably due to contact metamorphism, and granitic veins can be traced from this unit into the footwall at Lismer's Ridge. Sulphides are dominantly pyrite and pyrrhotite with local areas of trace to 1 volume percent chalcopyrite + pyrrhotite. Platinum group element concentrations are normally less than 25 ppb.
2. *Boundary Unit:* 5 to 20 m wide, but may be absent. It contains partly rounded to subangular, centimetre- and decimetre-size fragments of country rock (typically 10-25%), and cognate xenoliths of melagabbro, gabbro and less commonly leucogabbro to anorthosite in a matrix of gabbro to melagabbro ± aplite/granite, as in the Footwall Breccia. Sulphide minerals are mainly pyrite and pyrrhotite, locally up to 3 volume percent chalcopyrite + pyrrhotite occur; platinum group element contents are typically <75 ppb with local concentrations greater than 1000 ppb.
3. *Breccia Unit:* 20 m wide to greater than 100 m. It contains as much as 95% dominantly cognate xenoliths of gabbro to melagabbro and subordinate leucogabbro in a medium-grained matrix of similar composition; fragments are partly rounded to round probably due to partial assimilation, and centimetre to decimetre in size. Those greater than a metre are mainly footwall compositions (including Huronian Supergroup metasedimentary rocks) and tend to be larger with increasing proximity to the intrusive contact. Sulphide

minerals (1 to 5 volume percent pyrrhotite + chalcopyrite) occur as both bleb and disseminated types; platinum group element contents are highly varied, but most values range from 500-6000 ppb with local concentrations greater than 10,000 ppb.

4. *Inclusion-bearing Unit*: 10 to 50 m wide. It contains >90% autoliths of leucogabbro, subordinate gabbro and less melagabbro in a matrix of either medium-grained leucogabbro or gabbro; the leucogabbro xenoliths are subangular to partly rounded, dominantly decimetre to metre in scale, and appear to be stoped inclusions from the adjacent (overlying) Leucogabbronorite zone. Sulphide minerals include trace to 3 volume percent pyrrhotite + chalcopyrite; platinum group element contents range from 100-500 ppb with local concentrations greater than 1000 ppb.

Interestingly, the Breccia Unit, which shows the highest and most persistent sulphide-associated platinum group element mineralization, has the smallest proportion of footwall inclusions (<1%); perhaps an indication that chemical contamination from footwall lithologies is not a major controlling factor on mineralization.

Fine-grained gabbro and diabase dikes cut all of the above units as well as the Leucogabbronorite zone in the main part of the intrusion. These dikes are metamorphosed at a grade similar to the intrusion in the Dana North area and are distinct from younger dikes of the Sudbury swarm.

Drill hole data suggest that the dip of the contact of the Inclusion-bearing/Breccia zone with the footwall is at least 45° to 65° and toward the intrusion, whereas the apparent dip of the surface between the Inclusion-bearing Unit and Breccia Unit is steeper (~70°) and toward the intrusive contact. The attitude of metre-scale layering in the Leucogabbronorite zone adjacent to the mineralized Inclusion-bearing/Breccia zone is poorly constrained but is estimated to be near-vertical (~70° to 90° west and east) and possibly shallowing (i.e. less than 70° west dip) westward into the intrusion.

S/Se ratios for 13 of 15 samples (mineralized and unmineralized) from the Dana North and Lismer's Ridge areas have values from 500 to 2120, which are well within the magmatic range indicted by the Merensky and J-M reefs, and Konttijarvi-Portimo contact-type mineralization (i.e., 700-800 S/Se). Footwall rocks have low Pt, Pd and Au, and Pd/Pt and Cu/Ni are less than 1; these metal values indicate that the Archaean footwall rocks are not genetically related to the platinum group element mineralizing event(s). Estimates of the metal values for unmineralized magma that forms large parts of the intrusion or which are feeders, have less than 100 ppm Cu and anomalous Pt + Pd concentrations averaging 32 to 35 ppb, but their metal ratios, Pd/Pt and Cu/Ni, are both less than 1, which is unlike mineralized samples (*see* below). Analytical data for sulphide-bearing felsic and mafic dikes and the Boundary, Breccia and Inclusion-bearing Units all show moderate to high average Pt+Pd (peaking in the Breccia Unit, as expected), and all show Pd/Pt and Cu/Ni ratios based on metal averages in the range 1.1-4.8, distinct from the low sulphide, Cu-poor assemblages. The mineralized zones at the Bull Frog Zone of the East Bull Lake intrusion show the same geochemical features.

North Grid

In McWilliams Township, Mustang Minerals Corporation has identified mineralization (0.5-5 % disseminated chalcopyrite and pyrrhotite) in what they have termed a "Chaotic Zone" within their North Grid area, located roughly 500 m east of the Razor zone that belongs to Pacific North West Capital Coproration. This zone appears to be a continuation of the Marginal and Inclusion- and/or Fragment-bearing zones. It is 25 to 150 m wide in plan view and is continuous for ~3 km along strike (James et al. 2002b). It is at the margin of the River Valley intrusion in Dana Township and migrates into the intrusion as it continues southeast where it eventually occurs on the intrusion side of gabbronorites and quartz diorites that represent marginal phases of the intrusion (James et al. 2002b). Equigranular, poikilitic and pegmatitic gabbronorite and melagabbronorite are observed matrix lithologies of "Chaotic Zone" rocks. Cognate xenoliths form 50% or more of rocks in this zone and range in composition from websterite and orthopyroxenite to gabbronorite and anorthosite in which orthopyroxene, clinopyroxene and plagioclase are the primocryst phases. Layered olivine-bearing rocks (olivine websterite to troctolite in composition) overlie the "Chaotic Zone". These rocks may be part of the Olivine Gabbronorite zone and although they have no sulphide minerals they yield g/t platinum group element concentrations (James et al. 2002b).

Tomrose and Related Showings

The Tomrose occurrence has been examined numerous times since 1956 (*see* Appendix 1), with most activity occurring between 1964 and 1965, 1995 and 1999-2000. Stripping of 3 areas, performed in 1989 and 1994, provides good exposures over part of the occurrence (Photo 30). The occurrence consists of a heterogeneous breccia zone hosted by a fine-grained gabbronorite matrix. Mineralization style is similar to Azen Creek, with sulphide minerals occurring in the matrix and extensively in some of the breccia fragments. Sulphide minerals are commonly present in association with oxide-bearing (generally magnetite) fragments (*see* Photo 30). Assay data collected during this study (*see* Appendix 5, Crerar 1) found high copper values (300 to 1019 ppm), but with only sporadic platinum group element mineralization ranging from 70 to 357 ppb combined Au+Pt+Pd. Similar results were reported by Newman (1996) and Wood (2000).

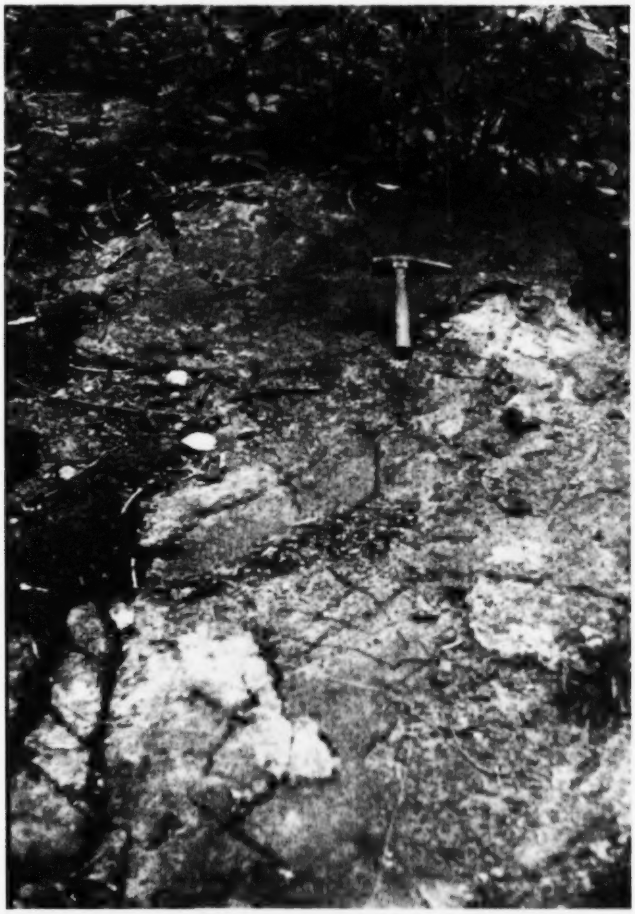


Photo 30. Stripped trench at Tomrose occurrence in the heterogeneous basal (inclusion-bearing) zone of the River Valley intrusion in Crerar Township. Note textural variation in zone, presence of possible pseudo-layering within the lower half of the field of view. Note also large, rusty-oxide-rich inclusion underneath the hammer. Hammer handle is 30 cm long. Station 99RME-0536. UTM 558494E 5160465N.

A large area of breccia forms a large hill immediately south-southwest of the main access road that leads to the Tomrose occurrence and which also runs through central Crerar Township. The breccia zone consists of large fragments of leucogabbronorite, locally thin to medium layered, in a buff- to rusty-weathering fine-grained matrix (Photo 31). Unlike the Tomrose occurrence, the matrix is extensively recrystallized, consisting mainly of fine-grained amphibole; this alteration may be related to a major shear zone, located on the south flank of the hill, that juxtaposes rocks of the River Valley intrusion against rocks of the Crerar gneiss association. Assay samples from the matrix to this breccia (*see* Appendix 5, Crerar 9) contain copper values ranging from 514 to 2378 ppm, and platinum group element mineralization ranging from below detection limits to 309 ppb combined Au+Pt+Pd.

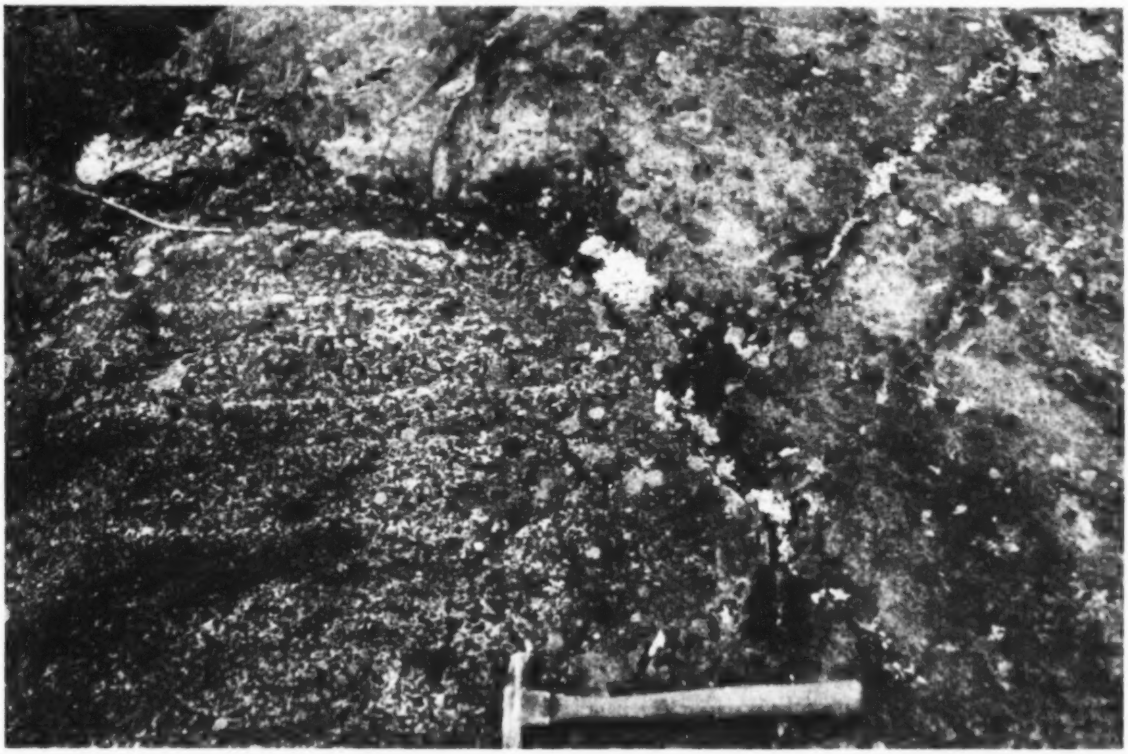


Photo 31. Large leucogabbro inclusion within buff-weathering, fine-grained, melanocratic rock, top of heterogeneous basal zone of River Valley intrusion, Crerar Township. Note layering within leucograbbronorite inclusion. Hammer handle is 30 cm long. Station 99RME-0543. UTM 557576E 5159583N.

As previously noted in the section on "Assay Results", historic pits in mafic gneiss located north of the Tomrose occurrence (*see* Appendix 5, Crerar 5, 6 and 7) locally contain copper values ranging from 2650 to 8094 ppm, significantly higher than observed in the better preserved rocks to the south. It is possible that the mafic gneiss hosting these pits is the highly deformed equivalent of the mineralized breccia unit observed at the Tomrose occurrence, although this has yet to be demonstrated through either textural or structural evidence. If this interpretation is correct, then mafic gneisses located south of the Sturgeon River in southwestern Dana Township, near the contact of the intrusion in that area, may also host similar mineralization.

Overview

All platinum group element-copper-nickel mineralization found to date within the River Valley intrusion occurs near the primary igneous contacts of the intrusion. Contact zone mineralization occurs as disseminated to blebby sulphide (chalcopyrite + pyrrhotite) in rocks that lie at (above or within) the intrusion's interface with the footwall (James et al. 2002a, 2002b). This zone is highly chaotic; footwall blocks and screens, mafic and felsic dikes, and varitextured, varied-composition gabbronoritic rocks, complicate the understanding of the exact host and source of the sulphides and the platinum group elements. The contact zone and its mineralization appears to be more chaotic where the body intrudes gneissic rocks, rather than syenitic or granitic rocks. This may be due to metamorphic and deformation differences in these areas. Both types of contact, though, seem to contain highly anomalous platinum group element values (James et al. 2002a, 2002b).

Hrominchuk (2000) observed that mineralization was absent or minimal where evidence for contamination of the magma within the Marginal or the overlying Inclusion and/or Fragment-Bearing zones was absent or minimal (i.e., few or no fragments). In contrast, mineralization is well developed where evidence for contamination is high, as indicated by small, resorbed fragments (Photo 32), blue quartz phenocrysts, and elevated Ti, K, Na, Zr, Y, LREE contents. Hrominchuk (2000) concluded that

Photo 32. Pegmatitic clot consisting of quartz, potassium feldspar, amphibole and sulphides in leucogabbronorite of the River Valley intrusion. Hrominchuk (2000) interpreted such clots as reaction zones to small country rock xenoliths incorporated within magma of the Marginal and Inclusion and/or Fragment-bearing zones. Hammer handle is 30 cm long. UTM 558630E 5165385N.

good grades of platinum-group element mineralization should result where fresh, PGE-rich magma had reached sulphide saturation through contamination, fractionation or other processes, and had sufficient R-factor (dynamic and turbulent magma). In the River Valley intrusion, these criteria are most prevalent in rocks of the Marginal and Inclusion and/or Fragment-Bearing zones. In contrast, S. Jobin-Bevans, in James et al. (2002b) observed that the Breccia Unit at Dana North, which shows the highest and most persistent sulphide-associated platinum group element mineralization, has the smallest proportion of footwall inclusions (<1%). This may indicate that chemical contamination from footwall lithologies was not a major controlling factor on mineralization.

To put the October 2002 mineral resource estimate for the Dana North and Lismer's Ridge property into perspective, it is useful to examine the resources present at some other platinum group element operations. This is done in Table 10, where the River Valley intrusion resource is compared with the Konttijarvi and Ahmavaara mineralized zones in the Konttijarvi-Suhanko intrusion of the Portimo Complex, Finland, as well as the Lac des Iles mine in northwestern Ontario. The Konttijarvi and Ahmavaara mineralized zones are thought to be direct analogues to the geology and mineralization described for the East Bull Lake suite intrusions (James et al. 2002b). As noted by James et al. (2002b) these data indicate that a bulk-tonnage operation is possible in the case of the East Bull Lake suite intrusions and exploration and evaluation should be approached using the scale and grade analogous to copper-gold porphyry systems. It is expected that potential economic contact-type platinum group element deposits would require a minimum 20 to 50 million tonnes at grades greater than 2.0 g/t Pd and Pt, dependent on commodity prices.

Table 10. Comparison of estimated copper-platinum group element mineral resources in several mafic intrusions.

Deposit and/or Intrusion	Tonnage and resource type	Pd g/t	Pt g/t	Au g/t	Cu wt. %	Cut-off grade	Source
River Valley Intrusion, Dana North and Lismer's Ridge deposits, ON	18.1 million (M, In) or	1.02	0.34	0.06	0.10	0.7 g/t Pd and Pt	Pacific North West Capital Corporation, press release, October 17, 2002
	23.4 million (M, In, If)	0.82	0.29	0.05	0.09		
Konttijarvi-Suhanko intrusion, Portimo Complex, Konttijarvi deposit, Finland	54.0 million (M, In, If)	1.44	0.40	0.10	0.16	0.5 g/t Pd, Pt and Au	Gold Fields Limited, press release, August 1, 2002
Konttijarvi-Suhanko intrusion, Portimo Complex, Ahmavaara deposit, Finland	99.8 million (M, In, If)	1.10	0.23	0.13	0.21	0.5 g/t Pd, Pt and Au	Gold Fields Limited, press release, August 1, 2002
	27.2 million (M only)	1.33	0.27	0.16	0.27		
Lac des Iles mine, Thunder Bay, ON	145.6 million (M, In)	1.57	0.17	0.12	0.06		North American Palladium Limited, press release, March 5, 2001

Abbreviations: g = grams, If = inferred, In = indicated, M = measured, t = tonne.

BUILDING STONE

Past-producing dimensional stone quarries are present in 2 of the better preserved areas of the River Valley intrusion north of the Sturgeon River in Dana and McWilliams Townships (*see* Figure 18). The Dana Black Granite quarry (Photo 33) is presently inactive, however, the Erana quarry is currently being exploited by Ontario Stone Products for a variety of grades of black crushed stone. In addition, a new quarry has been opened roughly 1.5 km west of the Erana quarry by Crea-mac Contracting Company Limited for the production of crushed stone for landscape purposes. Stone from the Dana Black Granite quarry was utilized in the construction of the Willet Green Miller Centre in Sudbury, the current headquarters of the Ontario Geological Survey, where it serves as flooring on the second and third floors of the building. Vos, Smith and Stevenato (1981) provide a history of the Erana quarry operation.

Photo 33. Part of the Dana stone quarry in the leucogabbronorite zone of the River Valley intrusion, Dana Township, as of October 1988. Note dark colour of the texturally well-preserved leucogabbronorite in the quarry. UTM 558630E 5165385N.

The overall heterogeneity of the River Valley intrusion in mineralogy, texture and state of metamorphism and deformation, limits the so called "Dana black granite" in its usefulness as an exterior building or facing stone. Primary features such as inclusions, layering, and rapid changes in grain size, as well as abundant shear zones, limit the size, and consistency of quarried blocks. The presence of amphibole coronas around primary pyroxene results in weathering around grain boundaries causing the stone to weather unevenly, especially when exposed to freeze-thaw conditions. In addition, local concentrations of sulphide can cause staining of the stone. Although large relatively homogeneous quarry blocks may be more difficult to obtain, smaller, more varied, quarry blocks, as well as extraction of crushed black to grey stone, can be easily exploited in many parts of Dana Township if a market could be found for these products.

HENRY AND LOUGHRIN TOWNSHIP INTRUSIONS

Introduction

It was previously thought that the belts of mafic intrusive rocks located in Henry and Loughrin townships represented the westward continuation of the River Valley intrusion, be they possible feeders to the intrusion or infolded layers (Lumbers 1971, 1973; Newman 1996). As previously noted herein, results from this study indicate that only the mafic intrusive rocks located in northeast Henry Township can be directly traced to rocks of the River Valley intrusion in Crerar Township. It should also be noted that the River Valley intrusion, both in Crerar and northeast Henry townships is hosted by rocks of the Crerar gneiss association.

In contrast, mafic intrusive rocks in northern Loughrin and northwest Henry townships are hosted by rocks of the Street gneiss association, have associated orthopyroxene hornblendite bodies, and only locally show preservation of primary textures and mineralogy, mainly in west-central Henry Township. For the purposes of this report, the East Bull Lake intrusive suite rocks in Henry and Loughrin townships are divided into 3 separate bodies, as follows (*see* Figure 2):

1. the Loughrin Lake intrusion, located in northern Loughrin and central Henry townships. It can be subdivided into two parts, a larger mass in northern Loughrin Township, and a small mass in central Henry Township.
2. the Third Concession intrusion, located in central Loughrin Township.
3. the Contact intrusion, a narrow (<500 m thick), linear body, located in southern Loughrin and Henry townships.

In map view, it is not clear if rocks of the Loughrin Lake intrusion are wholly separate from the River Valley intrusion, or if they are connected to one another by a thin septum of mafic rock, much like the east and west halves of the East Bull Lake intrusion. Resolving this question has been difficult, in part because it is unclear if gneissic granites in central Henry Township represent an area of country rock, or if they have simply intruded the East Bull Lake intrusive suite mafic rocks in this area. If they have intruded the mafic rocks, then it is possible the two bodies are genetically linked. If they are country rocks, then the map pattern may be explained by a combination of folding of the mafic rocks and the country rocks and juxtaposition due to younger north-trending faults.

On previous maps of the area, the Third Concession and Contact intrusions are shown to be continuous with one another, with their geometry resulting from regional folding. A difficulty with this interpretation is that the Contact intrusion is present at the Street-Crerar gneiss associations contact, whereas the Third Concession intrusion is hosted solely by rocks of the Street gneiss association.

Arguments in favour of the Loughrin Lake, Third Concession and Contact intrusions being separate intrusions from the River Valley intrusion include the following observations, which take into account the increased metamorphic grade and deformation of the mafic intrusive rocks present in Henry and Loughrin townships:

1. they are hosted by rocks of the Street gneiss association, believed to represent rocks preserved at a higher crustal level than the rocks represented by the Crerar gneiss association (Easton 2000);
2. they are associated with orthopyroxene hornblendite bodies, which are notably absent from the River Valley intrusion in Dana and Crerar townships;
3. the fact that ultramafic and anorthosite layers are not common in the Loughrin Lake, Third Concession and Contact intrusions, even in the better preserved parts of the Loughrin Lake intrusion. Such layers are common in the River Valley intrusion in Crerar Township. In addition, the River Valley intrusion in Crerar Township has a distinct stratigraphy, whereas the Loughrin Lake, Third Concession and Contact intrusions have no distinctly recognizable stratigraphic sequence.

If the Loughrin Lake, Third Concession and Contact intrusions are separate intrusions from the River Valley intrusion, then it follows that they may have considerably different mineral potential. The fact that ultramafic layers and a distinct stratigraphy have not been identified in the Loughrin Lake, Third Concession, and Contact intrusions may indicate that these intrusions were less dynamic during their crystallization, which would indicate a less favourable environment for platinum-group element enrichment according to Hrominchuk (2000). In addition, if they were separate and emplaced at a higher crustal level than the River Valley intrusion in Crerar Township, then these intrusions may not have been subjected to slow cooling, repeated magma injection, the presence of a large volume of magma and a dynamic magma chamber, all thought to be important in generating the mineralization observed in the River Valley intrusion in Dana and Crerar townships (Hrominchuk 2000; James et al. 2002a).

There are 2 main mafic intrusive rock types within the East Bull Lake intrusive suite bodies in Henry and Loughrin townships, namely, gabbronorite (e.g., sample 02RME-0103, Appendix 3) based on both CIPW normative mineralogy and observed primary mineralogy, and leucogabbronorite (e.g., sample 02RME-0106, Appendix 3). Locally, the leucogabbronorite can approach anorthosite in composition (>80% plagioclase). Over 65% of the exposed Loughrin Lake, Third Concession and Contact intrusions in Henry and Loughrin townships consist of leucogabbronorite. Gneissic varieties of these 2 main rock types are dominant in the area (*see* Photo 26a). Only in a few areas are primary mineralogy and textures partially preserved, the largest area of preserved rock being located in west-central Henry Township within the eastern part of the Loughrin Lake intrusion. In many outcrop areas, the gabbronorite and leucogabbronorite phases are interlayered on a centimetre- to metre-scale. In some of the larger outcrop ridges, gneissic varieties predominate on the flanks of the ridges, with foliated to undeformed, but partly to completely recrystallized varieties being preserved in the cores of the ridges. Easton and Hrominchuk (1999) and Hrominchuk (2000) noted a similar style of deformation and preservation in the River Valley intrusion in Dana and Crerar townships.

An important textural feature of the mafic and leucocratic gneisses of the East Bull Lake intrusive suite rocks in the study area is the general absence of layer-parallel or crosscutting leucosome phases (*see* Photo 26a). In contrast, leucosome phases are abundant in mafic gneisses present with the Street gneiss association (*see* Photo 8). The presence of leucosome is an important field tool in distinguishing between the 2 types of mafic gneisses. There are some exceptions to the generalization that leucosome is rare within rocks of the East Bull Lake intrusive suite, most notably, along the northern contact of the Loughrin Lake intrusion, however, these exceptions are restricted to areas of more intense deformation and metamorphism.

In several parts of the map area, particularly in Loughrin Township, previous workers did not always successfully delineate the different mafic gneisses, therefore, the older maps tend to exaggerate either the thickness or presence of East Bull Lake intrusive suite rocks. For example, a 500 m wide belt of mafic gneisses south of Loughrin Lake consists entirely of mafic gneisses of the Street gneiss association. Also, the thickness of the Third Concession intrusion in Loughrin Township is no more than 500 m thick, not 1000 m thick as previously indicated (Lumbers 1973).

Garnet is a common visible accessory phase within the gneissic varieties of the East Bull Lake intrusive suite in Henry and Loughrin townships, and appears to be more common than in similarly deformed rocks of the River Valley intrusion in western Crerar Township. This may result from higher metamorphic temperatures or pressures, or both, or it may reflect subtle compositional differences between the East Bull Lake intrusive suite bodies in Henry and Loughrin townships compared to the River Valley intrusion.

Attempts to delineate a generalized stratigraphic column for River Valley intrusive rocks in Henry and Loughrin townships have not been completely successful, even in areas where primary features are partly preserved. This in part reflects the abundance of monotonous leucogabbronorite within the study area, as well as complications resulting from the highly deformed nature of the rocks, and the relationship between the 2 main generations of structural fabrics within the study area. Nonetheless, in a general sense, where a primary intrusive contact of the intrusion is present, the common sequence of rock units appears to be orthopyroxene hornblendite (as pod-like bodies at the contact), gabbronorite (50-150 m thick), interlayered gabbronorite and leucogabbronorite (0-100 m thick), and leucogabbronorite (150-500 m thick). In detail, however, the observed stratigraphy at observed contacts varies considerably, in some areas only leucogabbronorite is present, in others, only orthopyroxene hornblendite and gabbronorite are present, in others, entire units are absent from the section.

Based on earlier maps, which suggested folding of East Bull Lake intrusive suite rocks in Henry and Loughrin townships (e.g., Lumbers 1973; Newman 1996), the author thought that it might be possible to observe the upper contact (roof) of the intrusion. So far, this goal has not been realised. If the presence of orthopyroxene hornblendite bodies can be used to infer the basal contact of the intrusion, then it follows that the northern contacts of the Loughrin Lake and the Third Concession intrusions might represent upper contacts. The northern contact of the Loughrin Lake intrusion, however, appears to be a structural contact. In contrast, the northern contact of the Third Concession intrusion has been engulfed by gneissic granite, which has served to obliterate any upper contact. Consequently, the nature of the roof of the intrusion, and the rock types that may be present there, remain enigmatic.

Several types of contacts, similar to those described for the River Valley intrusion, have been observed for the East Bull Lake intrusive suite bodies in Henry and Loughrin townships, and include primary intrusive contacts, secondary intrusive contacts, and fault contacts. The distribution of these contact types, where established, is shown on Figure 2. Of most importance to mineral exploration are primary intrusive contacts (e.g., Hrominchuk 2000; James et al. 2002a).

Loughrin Lake Intrusion

FORM AND GEOMETRY OF THE INTRUSION

The Loughrin Lake intrusion extends east from Halfway Lake near the Street-Loughrin townships boundary, through Loughrin and Henry lakes, to within 2 km of the Henry-Crerar township boundary. The intrusion is named for Loughrin Lake, which is located in northeastern Loughrin Township, near the approximate centre of the intrusion. The body has an east-northeast trend in Loughrin Township, and a more northwest trend in western Henry Township. This change in orientation occurs just east of Henry Lake, and may be coincident with a major north-trending fault that offsets the large Grenville swarm diabase dike present in the northern part of the study area.

The width of the Loughrin Lake intrusion is varied, ranging from 500 m to almost 2 km. The intrusion is cut by several north-trending faults, and intrusion width varies between individual fault blocks. This suggests that the observed width of the intrusion may reflect vertical motion that has affected the exposed structural level of the body between the fault blocks.

In some areas, most notably western Loughrin Township, the body exhibits some symmetry, with orthopyroxene hornblende and gabbronorite zones at its margins and leucogabbronorite and anorthosite in the core. Whether this symmetry indicates that the body is folded into a synclinal structure is undetermined, in part because there is no change in dip or orientation of gneissosity across the intrusion that is consistent with the presence of a fold structure.

Contacts of the Loughrin Lake intrusion are not generally exposed, although they generally appear to be sharp, in so far as ridges consisting of mafic intrusive rocks are typically found within a few metres of large outcrop areas of country rock. Dikes related to the intrusion are absent in the country rocks and there is little or no interfingering of the intrusion with the country rocks. The observation is consistent with the close correspondence between the geological and geophysically defined contacts of the Loughrin Lake intrusion, particularly in Loughrin Township.

Newman (1996) suggested that the northern contact of the Loughrin Lake intrusion was wholly tectonic. This appears to be the case east of Loughrin Lake, particularly on Boundary Road near the Henry-Janes townships boundary. Here, mafic intrusive rocks of the intrusion are highly flattened, locally developing leucosomes which are themselves flattened, and can best be described as straight gneisses. Farther west, the contact is not well exposed, however, the localized presence of orthopyroxene hornblendite bodies in close proximity to the northern contact suggests that the contact in western Loughrin Township is not as tectonized as it is to the east.

The contact of the Loughrin Lake intrusion with the gneisses of the Street gneiss association is exposed in several places in Henry Township. Where exposed, gabbronorite of the intrusion is in sharp contact with the gneisses. The contact is very irregular over short distances; this may reflect minor folding of the contact, but could also reflect injection of the contact along weaker horizons within the country rocks, or some combination of these two processes.

STRATIGRAPHY AND PETROGRAPHY

There are 2 main mafic intrusive rock types within the Loughrin Lake intrusion, namely, gabbronorite (e.g., sample 02RME-0103, Appendix 3) and leucogabbronorite (e.g., sample 02RME-0106, Appendix 3). Locally, the leucogabbronorite can approach anorthosite in composition (>80% plagioclase). Over 70% of the exposed Loughrin Lake intrusion consists of leucogabbronorite, with the remainder consisting of gabbronorite (20%), anorthosite (5 to 10%) and other phases (<5%). Texturally, gneissic varieties of these rock compositions predominate over lesser deformed varieties. Orthopyroxene hornblendite bodies occur on both flanks of the Loughrin Lake intrusion, but are more common along the southern contact. This difference could simply reflect the more tectonized character of the northern contact, particularly in the eastern part of the intrusion. Many of the orthopyroxene hornblendite bodies along the southern contact are quite large (>500 m long and >250 m thick), are commonly not in direct contact with the intrusion, and can occur as much as 1 km south of the intrusion's contact.

As previously noted, there may be a crude stratigraphic repetition across the western part of the Loughrin Lake intrusion. From apparent base to top, this sequence consists of scattered orthopyroxene hornblendite bodies, 100 to 300 m of gabbronorite, 300 to 500 m of leucogabbronorite, with some interlayered anorthosite horizons.

Even in the mineralogically better preserved parts of the Loughrin Lake intrusion in Henry Township, no stratigraphic sequence can be elucidated other than the general sequence of hornblendite, gabbronorite and leucogabbronorite noted above.

Lumbers (1973) showed the presence of a domal structure in the eastern part of the Loughrin Lake intrusion in Henry Township that was apparently cored by granitic gneiss. Mafic intrusive rocks surrounded this domal structure, but there was a thin belt of quartzite that separated the granitic gneiss from the mafic rocks. This sequence of rocks was similar to the map pattern Lumbers (1973) showed for the Tomrose area in Crerar Township, where he also showed a thin belt of quartzite at the contact of the River Valley intrusion. In the Tomrose area, results of this study indicated that some of the quartzite mapped by Lumbers (1973) was in fact an altered alkali feldspar granite, but overall, the pattern mapped by Lumbers (1973) was correct. In addition, the work of this study in the Tomrose area indicated that this was a primary intrusive contact of the River Valley intrusion. Consequently, the map pattern shown by Lumbers (1973) for north-central Henry Township could be interpreted as a refolded fold that exposed a significant strike-length of primary intrusive contact, and which might also result in the preservation of primary textures. If so, this contact would be of great economic interest.

Unfortunately, this interpretation was not borne out by detailed mapping. No quartzite or altered rocks that could be mistaken for quartzite were observed along this contact. Although some migmatitic country rock gneisses are preserved within the area of the domal structure, mainly on the northwestern side, much of the exposed rock in the dome consists of gneissic granite typical of the Geon 24 and 23 felsic intrusive rocks present in the study area. Several north-trending faults also cut this area, and much of the geometry of the intrusion in this area is due to fault offset, rather than the result of folding or warping of a continuous contact. Furthermore, no regular stratigraphic sequence was observed above this contact. In fact, most of the intrusive rocks found in contact with the Geon 24 and 23 gneissic granite are foliated to gneissic leucogabbro, with no orthopyroxene hornblendite being found anywhere along the contact. Elsewhere in Henry, Loughrin and Street townships, the presence of orthopyroxene hornblendite bodies appears to be a reliable indicator of basal contacts of East Bull Lake suite intrusions. In summary, the favoured interpretation is that this domal structure results mainly from intrusion of a Geon 24 to 23 granitic intrusion into both country rocks and the Loughrin Lake intrusion.

No obvious explanation as to why mineralogy and textures within the Loughrin Lake intrusion are best preserved in west-central Henry Township presents itself. There is no indication that it is located in a low strain zone due to regional fold patterns. The area is farthest away from the Geon 24 and 23 felsic intrusions present in this part of Henry and Loughrn townships, however, and perhaps this distance from the intrusions was a factor in preservation of mineralogy and textures.

GEOCHEMISTRY

Most of the available geochemical data from East Bull Lake intrusive suite rocks in Henry and Loughrin townships are from the Loughrin Lake intrusion, and consist of 6 samples reported by Obradovich (1999), 1 sample from Kirwan (1992) and 5 samples collected in this study; all are listed in Appendix 3. Samples 02RME-0054 and 02RME-0106, both gabbronorites, are geochemically very similar, even though sample 02RME-0054 is a gneissic rock collected from northwest Loughrin Township, and sample 02RME-0106 is a weakly deformed, slightly recrystallized gabbronorite collected from Henry Township. Sample 02RME-0103, a leucogabbro collected from the easternmost of the 3 Positano quarries, is very similar, at least in major elements, to a sample collected by Kirwan (1992) from the same general area.

Very few rocks in the River Vally intrusion have SiO_2 contents greater than 50 wt. %, however, both the gabbronoritic and leucogabbronoritic rocks from the Loughrin Lake intrusion typically have SiO_2 contents greater than 50 wt. %, ranging from 49 to 54 and 48 to 53 wt. %, respectively. Although rare earth element analyses for samples from the Loughrin Lake intrusion are limited (5 samples), they also appear to have slightly higher total rare earth contents (>25 ppm) than do most River Valley intrusion samples (generally <25 ppm). The difference in silica content appears to be the most significant geochemical difference between rocks of the Loughrin Lake and the River Valley intrusions, although as outlined in Table 11, there are other subtle differences between them. Overall, the data suggest a more evolved character to the magma that formed the Loughrin Lake intrusion compared to the River Valley intrusion. This more evolved character is reflected in higher total Fe_2O_3 and V, as well as higher incompatible elements such as Zr and total rare earth element contents. The higher total Fe_2O_3 content of the Loughrin Lake intrusion may be one of the reasons why this body contains more garnet than do equivalent rock types within the River Valley intrusion.

Table 11. Geochemical comparison of selected elements from the River Valley intrusion, the Loughrin Lake intrusion, and the Street metagabbro. Values in table reflect typical values for each intrusion, based mainly on gabbronoritic and leucogabbro compositions in order to facilitate comparison. Table is based on data contained in Appendix 3.

Intrusion	SiO_2 wt. %	TiO_2 wt. %	$Fe_2O_3^t$ wt. %	V ppm	Nb ppm	Zr ppm	Zr/Y	Total REE
River Valley intrusion	<50 38-52	<0.2	4 to 10	<100	<1	<20	1.5 to 3	<25
Loughrin Lake intrusion	>50 (48-53)	0.4 to 0.5	6 to 9	100 to 200	1	30	2 to 3	>25
Street metagabbro	<51 (48-52)	0.4 to 0.5	8 to 11	>200	1	40	3 to 4	>25

ECONOMIC GEOLOGY

Metallic Minerals

A considerable amount of assay data is currently available from the assessment files for the western part of this intrusion in Loughrin Township. For example, data from 379 assay samples collected by Mustang Resources Corporation had average values of 32 ppb combined Pt+Pd+Au, 52 ppm Cu and 30 ppm Ni (Wood 2002). Their highest assay sample contained 559 ppb Pt+Pd+Au, 346 ppm Cu and 865 ppm Ni (Wood 2002). The highest value reported by International Freegold Development Incorporated from part of the same area was from a sample containing 234 ppb combined Pt+Pd+Au, 954 ppm Cu, and 10 ppm Ni (Dimmell 2000). Aquiline Resources Incorporated (2000) reported the presence of a sulphide-bearing horizon hosted within rocks of the Loughrin Lake intrusion north-northeast of Halfway Lake, but they did not report any assay data from this horizon.

Hanych and Gorc (2000) reported a sample from the eastern part of this intrusion in Henry Township containing 72 ppb Pt, 20 ppb Pd. This sample was from the northernmost Positano quarry, and had average Pt and Pd values of 11 ppb each. A whole-rock geochemistry sample, collected by the author as part of this study, from the original quarry site examined by WIFCo and Dallaire (1985) contained 49 ppb Au, 15 ppb Pt, and 2 ppb Pd (sample 02RME-0106, Appendix 3). The highest assay result reported by Hanych and Gorc (2000), from a site located northwest of the Positano quarry, was 221 ppb Pt, 105 ppb Pd, and 440 to 850 ppm Cu. A whole-rock geochemistry sample, collected by the author, from the gabbronorite outcrop in Henry Township that was stripped in order to evaluate its building stone potential yielded an anomalous value of 560 ppb Au.

Rusty weathering zones, rusty patches in outcrop, or sulphide-bearing samples were not observed in the Loughrin Lake intrusion during this study. Inclusion- and/or fragment-bearing units, or possible gneissic equivalents, were also not observed in the Loughrin Lake intrusion.

Building Stone

Several rock units belonging to the Loughrin Lake intrusion in northwest Henry Township have been examined as possible building stones, notably leucogabbronorite gneiss (WIFCo and Dallaire 1985; Kirwan 1992) and gabbronorite (Positano 1995). All of these sites are characterized by minimal jointing, sufficient topography, and access to existing roads to make them viable prospects. Additional sites in the same intrusion in Henry Township meeting the same characteristics are also present (see Figure 15.2 in Easton 2002b).

Third Concession Intrusion

FORM, GEOMETRY AND STRATIGRAPHY

The Third Concession intrusion extends east from the southwestern corner of Loughrin Township to the Loughrin-Henry townships boundary. The body has an east-northeast trend, and is intersected by the east-oriented North and Third Concession roads, from which the intrusion is named. The width of the intrusion is generally about 500 m. The intrusion is cut by several, closely spaced, north-trending faults, which offset the intrusion by as much as 200 m.

The southern contact of the intrusion appears to be a primary intrusive contact. The intrusion is emplaced into quartzofeldspathic and migmatitic mafic gneisses of the Street gneiss association. As is typical of the study area, this contact appears to be sharp, with little associated diking in the country rocks near the contact, and little interfingering of intrusive phases and the country rocks. In places, a thin band of gabbronorite, 50 to 100 m thick, immediately overlies the contact, elsewhere, the body consists entirely of leucogabbro. Orthopyroxene hornblendite bodies are found in several places near the southern margin of the intrusion. The northern contact of the intrusion, at least north of Third Concession Road, appears to be truncated by a Geon 24 to 23 felsic intrusion of granitic composition. This younger intrusion incorporates large blocks of gneissic leucogabbronorite within it. Elsewhere along the northern contact, the intrusion appears to have been emplaced into mafic gneisses of the Street gneiss association, similar to those present along the southern contact.

The Third Concession intrusion consists almost entirely of gneissic rocks. Leucogabbro dominates, accounting for over 80% of the exposed intrusion; gabbronorite the remaining 20%; very minor anorthosite (<2%) is present within this intrusion.

ECONOMIC GEOLOGY

The highest assay result reported from the Third Concession intrusion came from a malachite-stained rock adjacent to a quartz vein that analyzed 558 ppb Au and 3557 ppm Cu. The highest assay result from mafic gneiss in the same area, was 62 ppb Au, 93 ppb Pt, 80 ppb Pd, and 485 ppm Cu (Hanych 2002). Rusty weathering zones, rusty patches in outcrops, or sulphide-bearing samples were not observed in any outcrops or samples of the Third Concession intrusion examined during this study. Inclusion- and/or fragment-bearing units, or possible gneissic equivalents, were also not observed within the Third Concession intrusion.

Contact Intrusion

FORM, GEOMETRY AND STRATIGRAPHY

The Contact intrusion extends east-northeast from the southwestern corner of Loughrin Township to central Henry Township. As with the Third Concession intrusion, it is generally about 500 m in width, and is cut by several, closely-spaced, north-trending faults, which offset the intrusion by as much as 200 m. It is named for the fact that it lies at the contact between the Street and Crerar gneiss associations.

The southern contact of the intrusion may be a tectonized primary intrusive contact. The intrusion is emplaced into tonalitic gneiss of the Crerar gneiss association along its southern contact. In the west, a thin band of gabbronorite, 50 to 100 m thick, immediately overlies the contact; elsewhere, the body consists entirely of leucogabbro. Orthopyroxene hornblendite bodies are found in several places near the southern margin of the intrusion in Loughrin Township. Less lithologic variation is seen in Henry Township, where the intrusion consists almost wholly of leucogabbro, with mafic phases and orthopryoxene hornblendite bodies apparently absent.

The northern contact of the intrusion is poorly exposed, and has not been observed. Gneisses of the Street gneiss association, or gneissic granite belonging to the Geon 24 to 23 felsic intrusive suite occur at or near the northern contact. In this respect, the northern contact resembles the northern contact of the Third Concession intrusion. The Contact intrusion consists almost entirely of gneissic rocks. Leucogabbro dominates, accounting for over 80 % of the exposed intrusion; gabbronorite the remaining 20 %, very minor anorthosite (<2 %) is present within this intrusion.

As previously noted, previous maps (e.g., Lumbers 1973; Newman 1996) show the Third Concession and Contact intrusions to be continuous with one another, with their geometry resulting from regional folding. In both intrusions, the northern contacts are locally cut by Geon 24 to 23 felsic intrusions. Although both basal contacts occur on the southern flanks of both bodies, the apparent basal (southern) contact of the Contact intrusion occurs at the Street-Crerar gneiss association contact, whereas the apparent basal (southern) contact of the Third Concession intrusion is hosted by rocks of the Street gneiss association. Any folding model requires a reversal in facing of the contacts, thus folding alone cannot explain why both basal contacts are south-facing, even if the difference in country rock character could be explained. A more likely scenario is the presence of a fault between the Third Concession and Contact intrusions, that results in structural repetition of the mafic inrusive rocks.

ECONOMIC GEOLOGY

Rusty weathering zones, rusty patches in outcrops, or sulphide-bearing samples were not observed in any outcrops or samples of the Contact intrusion examined during this study. Inclusion- and/or fragment-bearing units, or possible gneissic equivalents, were also not observed within the Contact intrusion in Henry or Loughrin townships.

STREET METAGABBRO

Form and Geometry

The largest area of rocks of the East Bull Lake intrusive suite in southeast Street Township occur in the Street metagabbro (*see* Figures 2, 21), a roughly 2.5 km long and 1 km wide body named and described by Easton (1999a) and Easton and Murphy (2002). The body has a generally crescentic, dome shape (Figure 21a) reflecting a type-2 fold interference pattern (Ramsay 1967) resulting from the folding of an early recumbent fold about a steeply inclined axis. In addition, the Street metagabbro is cut by several north-northeast-striking faults. The north contact of the body is probably tectonic and is characterized by intense shearing within both the anorthositic metagabbro and country rocks. In contrast, the south contact is sharp and juxtaposes anorthositic metagabbro against migmatitic (surreitic texture) amphibolite and quartzofeldspathic gneiss. In addition, there is a 300 to 400 m wide zone south of this contact, referred to as the "border zone", that consists of thinly layered melanoamphibolite (gabbronorite) which cuts surreitic amphibolite and quartzofeldspathic gneiss. This "border zone" may represent a feeder dike system to the Street metagabbro since melanoamphibolite in the border zone is indistinguishable from that in the main mass of the body.

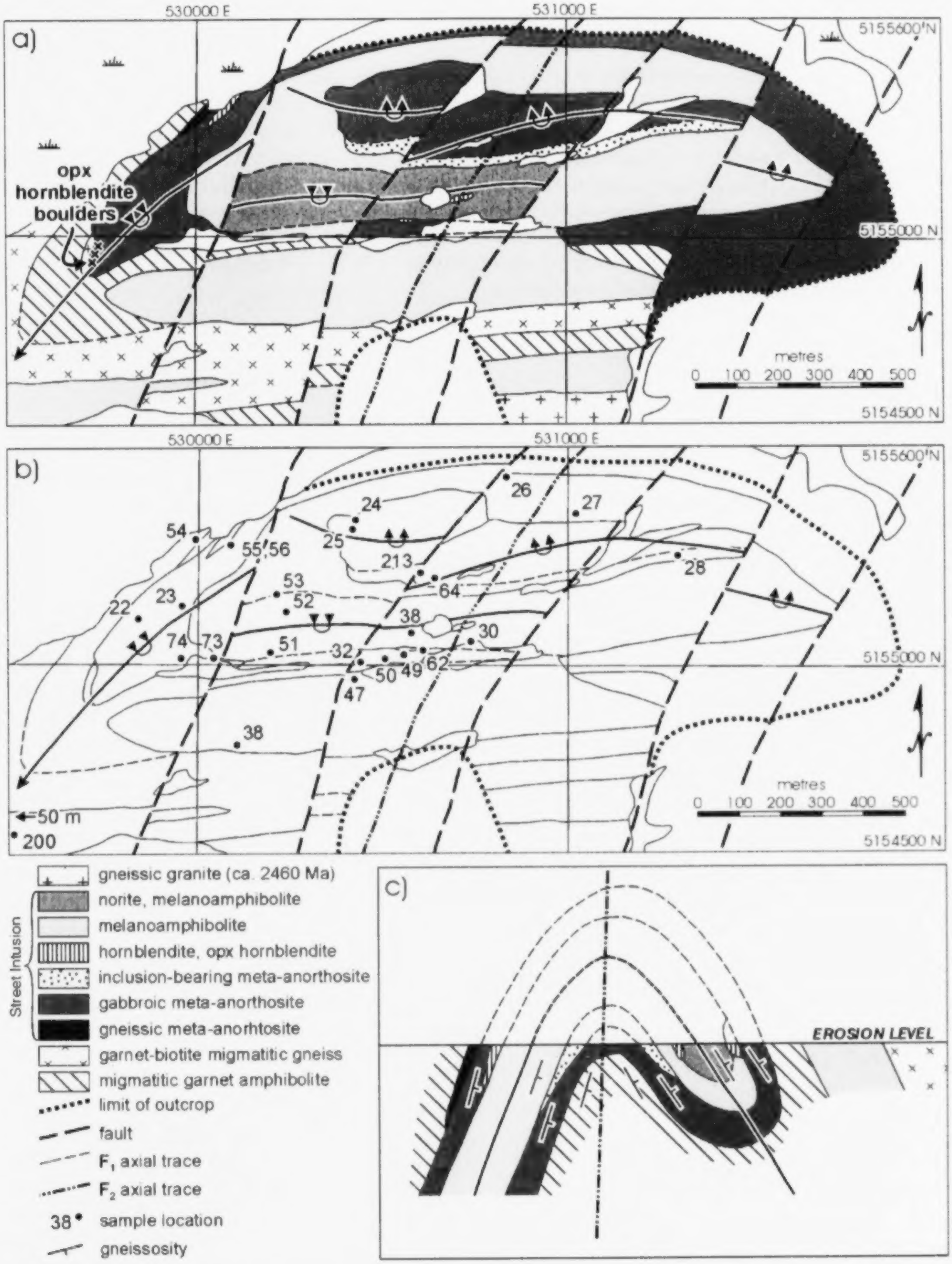

a)
530000 E
531000 E
5155600'N
5155000 N
5154500 N
opx hornblendite boulders
metres
0 100 200 300 400 500
b)
24
25
26
27
28
213
64
54
55,56
53
52
22
23
38
30
74
73
51
32
50
49
62
47
38
50 m
200
c)
EROSION LEVEL
gneissic granite (ca. 2460 Ma)
Street Intrusion
norite, melanoamphibolite
melanoamphibolite
hornblendite, opx hornblendite
inclusion-bearing meta-anorthosite
gabbroic meta-anorthosite
gneissic meta-anorhtosite
garnet-biotite migmatitic gneiss
migmatitic garnet amphibolite
limit of outcrop
fault
F₁ axial trace
F₂ axial trace
38 • sample location
gneissosity

Figure 21. **a)** Geological map of the Street anorthositic metagabbro body. **b)** Location of assay samples from the Street anorthositic metagabbro body. The prefix 96RME- and 98RME- in the sample numbers has been omitted for clarity. **c)** Inferred cross-section of the Street anorthositic metagabbro body showing the effects of folding on the body.

Stratigraphy and Petrography

Figure 19 shows a composite section through the metagabbro body and shows the main units present within the intrusion. Foliated anorthositic metagabbro and gabbroic meta-anorthosite comprise the lowermost unit (lower series) within the intrusion with a maximum thickness of roughly 150 m. Variation in plagioclase content within this unit may reflect primary layering in the body. This layering is cut by 50 to 75 cm wide mafic dikes, now garnet amphibolite, which were metamorphosed and deformed with the anorthositic rocks. Locally, near the top of this unit, are elongate inclusions of white-green-weathering, fine-grained epidote-garnet-plagioclase rock and dark-green-weathering amphibolite which may represent recrystallized anorthosite fragments and fragments of country rock. The lower series is re-exposed in the core of the body due to re-folding.

The lower series is overlain by the main series, a sequence of melanoamphibolite (*gabbronorite*), thinly layered melanoamphibolite (*gabbronorite*) and norite (*leuconorite*), that has a maximum thickness of 250 m. The relationship of the norite to the melanoamphibolite is unclear. The norite appears as both metre-scale pods and layers in the melanoamphibolite. The norite may simply represent areas that are more resistant to metamorphic recrystallization and may have no stratigraphic significance. This is suggested by the fact that primary orthopyroxene in the norite is armoured by pale amphibole, biotite, and garnet, and that a progression from almost completely preserved orthopyroxene (thinly armoured) to almost completely recrystallized (thick armour) is present. This is consistent with the observations of Easton and Hrominchuk (1999) who noted that orthopyroxene-bearing units of the River Valley intrusion were more resistant to metamorphic recrystallization than were other units.

Discontinuous hornblendite and orthopyroxene hornblendite (*olivine orthopyroxenite* and *olivine websterite*) layers and pods on the order of 100-150 m long and up to 15 m wide occur sporadically at the contact between the lower and main series. These pods contain 30-40% poikioblastic orthopyroxene. Orthopyroxene poikioblasts are smaller (<2 cm diameter) and subrounded in these pods with respect to the larger (>2cm) more euhedral, poikioblasts typical of the orthopyroxene hornblendites elsewhere in Street Township. Large erratics of orthopyroxene hornblendite occur along the western contact of the body, and may represent part of a small hornblendite body emplaced at the contact of the metagabbro and the host gneisses.

Figure 19 also compares the stratigraphy of the Street metagabbro with that of the East Bull Lake and Agnew Lake intrusions. The sequences are grossly similar with the Street metagabbro being most similar to the Agnew Lake intrusion particularly in terms of location of the inclusion-bearing zone and the fact that the gabbronorite overlying the gabbroic anorthosite zone is poorly layered. The most significant difference is that the Street metagabbro lacks part of the main series and all of the upper series present in both the East Bull Lake and Agnew Lake intrusions. Thickness differences between the lower and main series between the three intrusions (*see* Figure 19) may in part reflect tectonic thinning in the Street metagabbro.

Geochemistry

The mafic intrusions of the East Bull Lake intrusive suite possess the following key chemical characteristics, namely, low S tenor, low TiO_2 (<0.6 wt. %), moderate to high Al_2O_3 (16-25 wt. %) contents, moderate Mg numbers, high background PGE (35-40 ppb), and show light rare earth element enrichment with no or slightly positive Eu anomalies (Easton and Hrominchuk 1999; James et al. 2002a). The Street metagabbro shows all these characteristics, as shown in the chemical analyses listed in Appendix 3 and in Figures 8, 15, 24 and 25 in Easton and Murphy (2002).

As previously discussed under the section on the "Loughrin Lake Intrusion" and as summarized in Table 11, there are subtle geochemical differences between the River Valley intrusion, the Loughrin Lake intrusion, and the Street metagabbro. Of these 3 intrusions, the data suggess that the Street metagabbro is the most chemically evolved of the 3, based on its higher total Fe_2O_3 and V contents, as well as higher incompatible elements such as Zr. Although average total rare earth element content is not very different between the Loughrin Lake intrusion and the Street metagabbro (*see* Table 11), the Street metagabbro samples show a greater range in rare earth element contents between samples, and some of the highest total rare earth element contents. This increase in incompatable elements could be related to tapping of the upper levels of magma chambers present at intermediate crustal levels. If this were the case, it could be argued that the River Valley intrusion represents one of these magma chambers, and the Loughrin Lake intrusion and the Street metagabbro represent bodies emplaced at higher crustal levels that were fed from the River Valley intrusion or a similar body.

Economic Geology

Assay results from the Street metagabbro were previously presented in Easton (1999a) and Easton and Murphy (2002) and are not repeated here. It is worth noting, however, that 2 samples spatially associated with the Street metagabbro contained the highest Pt and Pd values that were obtained in an initial sampling program in Street Township in 1996, long before there was interest in exploring East Bull Lake intrusive suite rocks in the Grenville Province. These first 2 samples (96RME-0200, 96RME-0213, Appendix 3) yielded 49 and 112 ppb combined Pt and Pd. Sample 96RME-0200 was from a high-Mg number, non-migmatitic, melanoamphibolite, whereas sample 96RME-0213 was from a gabbroic meta-anorthosite. Additional sampling of the Street metagabbro was conducted in 1998, as reported in Easton (1999a). The additional samples with the highest PGE contents, samples 98RME-0024 and 98RME-0064 (Appendix 3), containing 166 and 229 ppb combined Pt and Pd, respectively, come from the same area of the body as sample 96RME-0213, suggesting that there is a discrete mineralized horizon present in this part of the intrusion. There is no obvious relationship between PGE content and Ni, Cu or S contents in these 3 samples. Four additional samples showing atypical PGE values were samples 98RME-0023, 98RME-0054, 98RME-0056 and 98RME-0073, which contain 59, 37, 82 and 38 ppb combined Pt and Pd, respectively (*see* Appendix 3). These 4 samples are all from the northwestern margin of the Street metagabbro.

The 1998 sampling indicated that initial sampling was reliable, and that atypical PGE values occur in two areas of the Street metagabbro, namely the central core and the northwestern margin. All samples with combined Pt and Pd greater than 37 ppb are from anorthositic gabbro or gabbroic anorthosite units, as is the case in the East Bull Lake intrusion (Peck et al. 1995).

Rusty weathering zones, rusty patches in outcrops, or sulphide-bearing samples were not observed in any outcrops or samples of the Street metagabbro examined during this study. Inclusion- and/or fragment-bearing units, or possible gneissic equivalents, were also not observed within the Street metagabbro.

OTHER BODIES

Small bodies of gneissic gabbronorite and melagabbronorite of the East Bull Lake intrusive suite occur throughout Street Township within parts of the Grenville Province underlain by rocks of the Street gneiss association. Some of these smaller bodies may represent large dikes or sills that intruded the Neoarchean country rocks but which were subsequently deformed and metamorphosed during the Grenville Orogeny.

Individual bodies and masses of gabbronoritic rocks consist of dark-green- to black-weathering, fine- to medium-grained gneissic amphibolite locally containing small, green pyroxene grains in addition to ubiquitous black hornblende. Leucosome is rare to absent in these rocks. Relict ophitic or diabase texture is rarely observed. Plagioclase content is difficult to estimate on either weathered or fresh surfaces in contrast to the moderate-magnesium rocks of the Nipissing gabbro intrusive suite present within the Grenville Province. Contacts with country rocks, generally with mafic gneisses of the Street gneiss association, are sharp and cut across the migmatitic layering present in the mafic gneisses. Many outcrops exhibit very thin layering subparallel to the regional fabric which may represent relict compositional layering. The origin of this layering is not known.

References

Aquiline Resources Incorporated. 2000. A report on exploration fieldwork available in the fall 2000; Sudbury Resident Geologist's office, Loughrin Township, assessment file SP#0007, not paginated.

Ashwal, L.D. and Wooden, J.L. 1989. River Valley pluton, Ontario: A late-Archean/early Proterozoic anorthositic intrusion in the Grenville Province; Geochimica et Cosmochimica Acta, v.53, p.633- 641.

Bennett, G., Dressler, B.O. and Robertson, J.A. 1991. The Huronian Supergroup and associated intrusive rocks; *in* Geology of Ontario, Chapter 14, Ontario Geological Survey, Special Volume 4, pt.1, p.549-591.

Bethune, K.M. 1997. The Sudbury dyke swarm and its bearing on the tectonic development of the Grenville Front, Ontario, Canada; Precambrian Research, v.85, p.117-146.

Bethune, K.M. and Davidson, A. 1997. Grenvillian metamorphism of the Sudbury diabase dyke-swarm: from protolith to two-pyroxene–garnet coronite; Canadian Mineralogist, v.35, p.1191-1220.

Born, P. 1979. Geology of the East Bull Lake mafic intrusion, District of Algoma, Ontario; unpublished MSc thesis, Laurentian University, Sudbury, Ontario, 147p.

Breaks, F.W. and Moore, J.M. 1992. The Ghost Lake batholith, Superior Province of northwestern Ontario: a fertile, S-type, peraluminous granite-rare-element pegmatite system; Canadian Mineralogist, v.30, p.835-875.

Brons, D. 1984. Geology of the Drury gabbro-anorthosite intrusion; unpublished MSc thesis, Laurentian University, Sudbury, Ontario.

Bruce, E.L. 1932. Geology of the Townships of Janes, McNish, Pardo and Dana; Ontario Department of Mines, Annual Report, v. 41, pt. IV., 128p.

Buchan, K.L. and Ernst, R.E. 1994. Onaping fault system: age constraints on deformation of the Kapuskasing structural zone and units underlying the Sudbury structure; Canadian Journal of Earth Sciences, v. 21, p.1197-1205.

Buckley, S.B., Easton, R.M., Ford, F.D. and Lobanok, L. 1997. Analysis of P-T conditions along the Grenville Front east of Sudbury, Ontario; Geological Association of Canada-Mineralogical Association of Canada-Canadian Geophysical Union, Program with Abstracts, v.22, p.A-20.

Cape, D.F. 1973. A petrologic and geochemical study of a gabbro, anorthositic gabbro intrusion and neighbouring volcanics, northwest corner of May Township; unpublished BSc thesis, University of Windsor, Windsor, Ontario, 62p.

Card, K. D. 1978. Geology of the Sudbury-Manitoulin area; Ontario Geological Survey, Geological Report 166, 238p.

Card, K.D. 1992. Circa 1.75 Ga ages for plutonic rocks from the Southern Province and adjacent Grenville Province: what is the expression of the Penokean orogeny?: Discussion; *in* Radiogenic Age and Isotopic Studies: Report 6; Geological Survey of Canada Paper 92-2, p.227-228.

Card, K.D. and Lumbers, S.B. 1975. Sudbury-Cobalt; Ontario Geological Survey, Map 2361.

Card, K.D. and Poulsen, K.H. 2000. Archean and Paleoproterozoic geology and metallogeny of the southern Canadian Shield; Exploration and Mining Geology, v.7, p.181-215.

Card, K.D., Church, W.R., Franklin, J.M., Frarey, M.J., Robertson, J.A., West, G.F. and Young, G.M. 1972. The Southern Province; *in* Variations in Tectonic Styles in Canada, Geological Association of Canada, Special Paper 11, p. 335-380.

Carr, S.D., Easton, R.M., Jamieson, R.A. and Culshaw, N.G. 2000. Geologic transect across the Grenville Orogen of Ontario and New York; Canadian Journal of Earth Sciences, v. 37, p. 193-216.

Chen,Y.D., Krogh, T.E. and Lumbers, S.B. 1995. Neoarchean trondhjemitic and tonalitic orthogneiss identified within the northern Grenville Province in Ontario by precise U-Pb dating and petrologic studies; Precambrian Research, v.72, p.263-281.

Chubb, P.T. 1994. Petrogenesis of the eastern portion of the Early Proterozoic East Bull Lake Gabbro-Anorthosite Intrusion, District of Sudbury/Algoma, Ontario; unpublished MSc thesis, Laurentian University, Sudbury, Ontario, 230p.

Collins, W.H. 1913. Geology of a portion of the Sudbury map-area south of Wanapitei Lake, Ontario; Geological Survey of Canada, Summary Report 1913, p.189–195.

Conrod, D. 1988. Petrology, geochemistry and PGE potential of the Nipissing intrusions; unpublished MSc thesis, University of Toronto.

Conrod, D. 1989. The petrology and geochemistry of the Duncan Lake, Beaton Bay, Milner Lake and Miller Lake Nipissing intrusions within the Gowganda area, District of Timiskaming; Ontario Geological Survey, Open File Report 5701, 201p.

Corfu, F. and Andrews, A.J. 1986. A U-Pb age for mineralized Nipissing diabase, Gowganda, Ontario; Canadian Journal of Earth Sciences, v.23, p.107-109.

Corfu, F. and Easton, R.M. 2000. U-Pb evidence for polymetamorphic history of Huronian rocks underlying the Grenville Front Tectonic Zone east of Sudbury, Ontario; Chemical Geology, v. 172, p.149-171.

Culshaw, N.G., Corrigan, D., Drage, and Wallace, P. 1988. Georgian Bay geological synthesis: Key Harbour to Dillion, Grenville Province of Ontario; *in* Current Research, Part C, Geological Survey of Canada, Paper 88-1C, p.129-133.

Davidson, A. 1986. A new look at the Grenville Front in Ontario; Geological Association of Canada, Ottawa'86, Field Trip 15, Guidebook, 31p.

Davidson, A. 1997. New information on the Grenville Front near Sudbury; 43rd Annual Institute on Lake Superior Geology, Proceedings, v.43, pt.3, 38p.

Davidson, A. 1998. Questions of correlation across the Grenville Front east of Sudbury, Ontario; *in* Current Research, 1998-C, Geological Survey of Canada, p.145-154.

Davidson, A., and van Breemen, O. 1994. U-Pb ages of granites near the Grenville Front, Ontario; *in* Radiogenic age and isotopic studies: report 8, Geological Survey of Canada, Current Research 1994-F, p.107–114.

Davidson, A., van Breemen, O. and Sullivan, R.W. 1992. Circa 1.75 Ga ages for plutonic rocks from the Southern Province and adjacent Grenville Province: what is the expression of the Penokean orogeny?; *in* Radiogenic Age and Isotopic Studies: Report 6; Geological Survey of Canada Paper 92-2, p. 107-118.

Davis, D.W. 1992. Age constraints on deposition and provenance of Archean sediments in the southern Abitibi and Pontiac subprovinces from U-Pb analyses of detrital zircons; *in* Abitibi-Grenville Transect, Lithoprobe Report 25, p.147-150.

Davis, D.W., Pezzutto, F. and Ojakangas, R.W. 1990. The age and provenance of metasedimentary rocks in the Quetico Subprovince, Ontario, from single zircon analyses: implications for Archean sedimentation and tectonics in the Superior Province; Earth and Planetary Science Letters, v.99, p.195-205.

Debicki, R.L. 1990. Stratigraphy, paleoenvironment and economic potential of the Huronian Supergroup in the southern Cobalt embayment; Ontario Geological Survey, Miscellaneous Paper 148, 154p.

Debon, F. and Le Fort, P. 1983. A chemical-mineralogical classification of common plutonic rocks and associations; Transactions of the Royal Society of Edinburgh, Earth Sciences, v.73, p.135-149.

Deer, W.A., Howie, R.A. and Zussman, J. 1966. An introduction to the rock-forming minerals; Longman, London, 528p.

DeGagne, P. 1982. Geology of the Norduna Intrusion; unpublished BSc thesis, Laurentian University, Sudbury, Ontario, 20p.

Dickin, A.P. 1998. Pb isotope mapping of differentially uplifted Archean basement: a case study from the Grenville Province, Ontario; Precambrian Research, v.91, p.445-454.

Dimmell, P.M. 2000. Work report: Phase 1 PGM-C Property, prepared for International Freegold Mineral Development Incorporated; Sudbury Resident Geologist's office, Loughrin Township, assessment file SP#0008, 31p.

Dressler, B.O. 1979. Geology of McNish and Janes Townships; Ontario Geological Survey, Report 191, 91p.

Dressler, B.O., Gupta, V.K. and Muir, T.L. 1991. The Sudbury Structure; *in* Geology of Ontario, Chapter 15, Ontario Geological Survey, Special Volume 4, pt.1, p.593-625.

Easton, R.M. 1992. The Grenville Province; *in* Geology of Ontario, Chapter 19, Ontario Geological Survey, Special Volume 4, pt.2, p.713-904.

Easton, R.M. 1996. Geology of garnetiferous gneisses in Street Township, District of Sudbury; *in* Summary of Field Work and Other Activities, 1996, Ontario Geological Survey, Miscellaneous Paper 166, p.70-73.

Easton, R.M. 1998. New observations related to the mineral potential of the Southern Province and the Grenville Front tectonic zone east of Sudbury; Ontario Geological Survey, Open File Report 5976, 28p.

Easton, R.M. 1999a. Platinum group elements, nickel, copper and chromium potential of mafic rocks within the Grenville Front tectonic zone east of Sudbury, *in* Summary of Field Work and Other Activities, 1998, Ontario Geological Survey, Miscellaneous Paper 169, p.68-69.

Easton, R.M. 1999b. Geologic Time Scale; *in* Encyclopedia of Geochemistry, Kluwer Academic Publishers, Boston, Mass, p.295-298.

Easton, R.M. 2000. Variation in crustal level and large-scale tectonic controls on rare-metal and platinum-group element mineralization in the Southern and Grenville provinces; *in* Summary of Fieldwork and Other Activities 2000, Ontario Geological Survey, Open File Report 6032, p.28-1 to 28-16.

Easton, R.M. 2001. Geology of Glen Afton (River Valley area)(41I/9); Ontario Geological Survey, Preliminary Map P.3453, scale 1:50 000.

Easton, R.M. 2002a. Geology of mafic intrusive rocks of Flett and Angus townships, Grenville Province; Ontario Geological Survey Open File Report 6090, 70p.

Easton, R.M. 2002b. Geology and mineral potential of Henry and Loughrin townships, Grenville Province; *in* Summary of Field Work and Other Activities 2002, Ontario Geological Survey, Open File Report 6100, p.15-1 to 15-16.

Easton, R.M., Buckley, S.G., Lobanok, E. and James, R.S. 1996. Grenville-Southern Province Relationships in Street Township, District of Sudbury; *in* Summary of Field Work and Other Activities 1996, Ontario Geological Survey, Miscellaneous Paper 166, p. 66-69.

Easton, R.M., Davidson, A. and Murphy, E.I. 1999. Transects across the Southern-Grenville Province Boundary near Sudbury, Ontario; Guidebook #A2, Sudbury '99, Geological Association of Canada, 52 p.

Easton, R.M. and Hrominchuk, J. 1999. Geology and copper-platinum group element mineral potential of Dana and Crerar townships, River Valley area, Grenville Province; *in* Summary of Field Work and Other Activities, 1999, Ontario Geological Survey, Open File Report 6000, p.30-1 to 30-35.

Easton, R.M. and Hrominchuk, J.L. 2001a. Precambrian geology of Crerar township, Grenville Province; Ontario Geological Survey, Preliminary Map P.3432, scale 1:20 000.

Easton, R.M. and Hrominchuk, J.L. 2001b. Precambrian geology of Dana township, Grenville Province; Ontario Geological Survey, Preliminary Map P.3433, scale 1:20 000.

Easton, R.M. and Hrominchuk, J.L. 2002. Whole-rock and mineral chemistry, assay, and petrographic data for the River Valley intrusion, Crerar and Dana townships, Grenville Province, Ontario; Ontario Geological Survey, Miscellaneous Release-Data 95, 1 diskette containing 8 tables.

Easton, R.M. and James, R.S. 1997a. Revisiting the disappearance of the Huronian in the Sudbury-Crerar area: Part 1. The Amphibolite Story; Geological Association of Canada-Mineralogical Association of Canada-Canadian Geophysical Union, Program with Abstracts, v.22, p.A43.

Easton, R.M. and James, R.S. 1997b. Revisiting the disappearance of the Huronian in the Sudbury-Crerar area: Insights from the Geochemistry of Amphibolites and Paragneisses; 43rd Institute on Lake Superior Geology, Proceedings, Volume 43, pt.1, p.19-20.

Easton, R.M. and Murphy, E. 2000. Geology of Street Township; Ontario Geological Survey, Preliminary Map P.3427, scale 1:20 000.

Easton, R.M. and Murphy, E. 2002. Precambrian Geology of Street Township, District of Sudbury; Ontario Geological Survey, Open File Report 6078, 149p.

Easton, R.M. and terMeer, M. in prep. Geology of Henry and Loughrin townships; Ontario Geological Survey, Preliminary Map, scale 1:20 000.

Ernst, R.E. and Buchan, K.L. 2001. Large mafic magmatic events through time and links to mantle-plume heads; *in* Mantle Plumes: their identification through time, Ernst, R.E. and Buchan, K.L., editors, Geological Society of America, Memoir 352, p.483-575.

Fahrig, W. F. 1987. The tectonic settings of continental mafic dyke swarms: Failed arm and early passive margin; *in* Mafic Dyke Swarms, Halls, H.C. and Fahrig, W. F., editors, Geological Association of Canada, Special Paper 34, p.331-348.

Fairbairn, H.W. 1939. Geology of the Ashigami Lake area; Ontario Department of Mines, Annual Report, v.48, pt.10, 15p.

Fedo, C.M., Young, G.M., Nesbitt, H.W. and Hanchar, J.M. 1997. Potassic and sodic metasomatism in the Southern Province of the Canadian Shield: evidence from the Paleoproterozoic Serpent Formation, Huronian Supergroup, Canada; Precambrian Research, v.84, p.17-36.

Fralick, P.W. and Miall, A.D. 1989. Sedimentology of the Lower Huronian Supergroup (Early Proterozoic), Elliot Lake area, Ontario, Canada; Sedimentary Geology, v.63, p.127-153.

Gates, B.I. 1991. Sudbury mineral occurrence study; Ontario Geological Survey, Open File Report 5771, 235p.

Gordiyenko, V.V. 1971. Concentration of Li, Rb and C in potash feldspar and muscovite and criteria for assessing the rare-metal mineralization in granitic pegmatites; International Geology Review, v.13, p.134-142.

Grammatikopoulus, T., Macdonald, J., Gerow, M. and Easton, R.M. 1999. Mineralogical, geochemical, electron microprobe examination and beneficiation of garnet-bearing rocks, Ontario, Canada; Internal Report, Ministry of Northern Development and Mines, 70p.

Grant, J.A., Pearson, W.J., Phemister, T.C. and Thomson, J.E. 1962. Broder, Dill, Neelon, and Dryden townships; Ontario Department of Mines, Geological Report 9, p.1-24.

Halls, H.C. and Bates, M.P. 1990. Evolution of the 2.45 Ga Matachewan Dike Swarm, Canada; *in* Mafic dikes and emplacement mechanisms, A.A. Balkema, Rotterdam, p.237-249.

Hamlyn, P.R., Keays, R.R., Cameron, W.E., Crawford, A.J. and Waldron, H.M. 1985. Precious metals in magnesian low Ti lavas: Implications for metallogenesis and sulfur saturation in primary magmas; Geochimica et Cosmochemica Acta, v.49, p.1797-1811.

Hamlyn, P.R. and Keays, R. R. 1986. Sulfur saturation and second-stage melts: Application to the Bushveld platinum metal deposits; Economic Geology, v.81, p.1431-1445.

Hart, T.R., Gibson, H.L., Lesher, M.C. and Campbell, I.H. 2001. Trace element geochemistry and petrogenesis of felsic metavolcanic rocks associated with volcanogenic Cu-Zn-Pb massive sulphide deposits; Geological Society of America, Abstracts with Program, v.33, no.6, p.A185.

Haynch, W. 2002. Geological report on the River Valley Project, southeast Loughrin property, Claim 1244242 and Lefrancois Land Patent, prepared for Platinum Group Metals Limited; Sudbury Resident Geologist's office, Loughrin Township, assessment file SP#0013, 25p.

Haynch, W. and Gore, D. 2000. Geological and geochemical report on the Henry Block, for Platinum Group Metals Limited; Sudbury Resident Geologist's office, Henry Township, assessment file SP#0008, 18p.

Heaman, L.M. 1997. Global magmatism at 2.45 Ga: Remnants of an ancient large igneous province?; Geology, v.25, p.299-302.

Hickey, R.L. and Frey, F.A. 1982. Geochemical characteristics of boninite series volcanics: implications for their source; Geochimica et Cosmochemica Acta, v.46, p.2099-2155.

Hoffman, P.F. 1989. Precambrian geology and tectonic history of North America; *in* The Geology of North America-An Overview; Geological Society of America, Decade of North American Geology, Volume A, p.447-512.

Hofmann, H.J. 1990. Precambrian time units and nomenclature – the geon concept; Geology, v. 18, p. 340-341.

Holm, D.K., Schneider, D.A., O'Boyle, C., Hamilton, M.A., Jercinovic, M.J. and Williams, M.L. 2001. Direct timing constraints on Paleoproterozoic metamorphism, southern Lake Superior region: results from SHRIMP and EMP U-Pb dating of metamorphic monazites; Geological Society of America, Abstracts with Program, v.33, no.6, p.A-401.

Hriskevich, M.E. 1968. Petrology of the Nipissing diabase sill of the Cobalt area, Ontario, Canada; Geological Society of America, Bulletin, v.79, p.1387-1404.

Hrominchuk, J.L. 1999. Geology, stratigraphy and copper-platinum group element mineralization of the River Valley Intrusion, Dana Township; *in* Summary of Field Work and Other Activities, 1999, Ontario Geological Survey, Open File Report 6000, p.31-1 to 31-9.

Hrominchuk, J.L. 2000. Geology, stratigraphy and copper-nickel-platinum group element mineralization of the River Valley Intrusion; *in* Summary of Field Work and Other Activities, 2000, Ontario Geological Survey, Open File Report 6032, p.29-1 to 29-12.

Hubbard, L. 1998. A petrographic study of Proterozoic meta-pyroxenites of the Grenville Front Tectonic Zone, Sudbury, Ontario; unpublished BSc thesis, Laurentian University, Sudbury, Ontario, 48p.

Innes, D.G. 1972. Proterozoic volcanism and associated sulphide-bearing metasediments in the Sudbury area, Ontario; unpublished BSc thesis, Laurentian University, Sudbury, Ontario, 66p.

Innes, D.G. 1977. Proterozoic volcanism in the Southern Province of the Canadian Shield; unpublished MSc thesis, Laurentian University, Sudbury, Ontario, 161p.

Irvine, T.N. 1982. Terminology for layered intrusions; Journal of Petrology, v.23, p.127-162.

James, R.S. and Born, P. 1985. Geology and geochemistry of the East Bull Lake intrusion, District of Algoma, Ontario; Canadian Journal of Earth Sciences, v.22, p.968-979.

James, R.S., Easton, R.M., Peck, D.C. and Hrominchuk, J.L. 2002a. The East Bull Lake intrusive suite: remnants of a ~2.48 Ga large igneous and metallogenic province in the Sudbury area of the Canadian Shield; Economic Geology, v. 97, p.1577-1606.

James, R.S., Jobin-Bevans, S., Easton, R.M., Wood, P., Hrominchuk, J.L., Keays, R.R. and Peck, D.C. 2002b. Platinum group element mineralization in Paleoproterozoic basic intrusions in central and northeastern Ontario, Canada; *in* Geology, geochemistry, mineralogy and mineral beneficiation of platinum group elements, L.J. Cabri, editor, Canadian Institute of Mining and Metallurgy, Special Publication 54, p.339-365.

Junnila, R.M. and Young, G.M. 1995. The Paleoproterozoic upper Gowganda Formation, Whitefish Falls area, Ontario, Canada: subaqueous deposits of a braid delta; Canadian Journal of Earth Sciences, v.32, p.197-209.

Kamineni, D.C. 1986. A petrochemical study of calcic amphiboles from the East Bull Lake anorthosite-gabbro layered complex, District of Algoma, Ontario; Contributions to Mineralogy and Petrology, v.93, p.471-481.

Kamo, S.L., Krogh, T.E. and Kumarapeli, P.S. 1995. Age of the Grenville dyke swarm, Ontario-Quebec: Implications for the timing of Iapetan Rifting; Canadian Journal of Earth Sciences, v.32, p.273-280.

Keays, R.R. 1995. The role of komatiitic and picritic magmatism and S-saturation in the formation of ore deposits; Lithos, v.34, p.1-18.

Keays, R.R., Vogel, D.C., James, R.S., Peck, D.C., Lightfoot, P.C. and Prevec, S.A. 1995. Metallogenic potential of the Huronian-Nipissing magmatic province; The Canadian Mineralogist, v.33, p.932-933.

Ketchum, J.W.F. and Davidson, A. 2000. Crustal architecture and tectonic assembly of the Central Gneiss Belt, southwestern Grenville Province, Canada: a new interpretation; Canadian Journal of Earth Sciences, v.37, p.217-234.

Kilpatrick, J.A. and Ellis, D.J. 1992. C-type magma: igneous charnockites and their extrusive equivalents; Transactions of the Royal Society of Edinburgh, Earth Sciences, v.83, p.155-164.

Kindle, L.F. 1933. Moose Mountain-Wanapitei Lake area; Ontario Bureau of Mines, Annual Report 41, pt.4, p.29-49.

Kirwan, J.L. 1992. Reconnaissance geological survey, Positano granite claim, Henry Twp., Ontario; Sudbury Resident Geologist's office, Henry Township, assessment file SP#0002, 15p.

Kretz, R. 1983. Symbols for the rock-forming minerals; American Mineralogist, v.68, p.277-279.

Krogh, T.E. 1994. Precise U-Pb ages for Grenvillian and pre-Grenvillian thrusting of Proterozoic and Archean metamorphic assemblages in the Grenville Front tectonic zone, Canada; Tectonics v.13, p. 963-982.

Krogh, T.E. and Davis, G.L. 1970. Isotopic ages along the Grenville Province of Ontario; Carnegie Institution of Washington, Yearbook 68, p. 309-313.

Krogh, T.E., Davis, D.W. and Corfu, F. 1984. Precise U-Pb zircon and baddelyite ages for the Sudbury Structure; *in* Geology and Ore Deposits of the Sudbury Structure, Ontario Geological Survey Special Volume 1, p.431-446.

Krogh, T.E., Corfu, F., Davis, D.W., Dunning, G.R., Heaman, L.M., Kamo, S.L., Machado, N., Greenough, J.D. and Nakamura, E. 1987. Precise U-Pb isotopic ages of diabase dykes and mafic to ultramafic rocks using trace amounts of baddeleyite and zircon; *in* Mafic Dyke Swarms, Geological Association of Canada, Special Paper 34, p.147-152.

Krogh, T.E., Kamo, S.L. and Bohor, B.F. 1996. Shock metamorphosed zircons with correlated U-Pb discordance and melt rocks with concordant protolith ages indicate an impact origin for the Sudbury structure; *in* Earth Processes: Reading the Isotopic Code, American Geophysical Union, Geophysical Monograph 95, p.343-353.

Kwon, S.T., Tilton, G.R. and Grunenfelder, M.H. 1989. Pb isotope relationships in carbonatites and alkalic complexes: An overview; *in* Carbonatites-Genesis & Evolution, Unwin-Hyman, London, p.360-387.

Le Maitre, R.W. 1989. A classification of igenous rocks and glossary of terms; Blackwell Scientific Publications, Oxford, United Kingdom, 193p.

Lesher, C.M., Goodwin, A.M., Campbell, I.H. and Gorton, M.P. 1986. Trace-element geochemistry of ore-associated and barren, felsic metavolcanic rocks in the Superior Province, Canada; Canadian Journal of Earth Sciences, v.23, p.222-237.

Lightfoot, P.C. and Naldrett, A.J. 1996. Petrology and geochemistry of the Nipissing gabbro: exploration strategies for nickel, copper, and platinum group elements in a large igneous province; Ontario Geological Survey, Study 58, 81p.

Lumbers, S.B. 1971. River Valley area; *in* Summary of Field Work, 1971, Ontario Department of Mines and Northern Affairs, Miscellaneous Paper 49, p.90-97.

Lumbers, S.B. 1973. River Valley area; Ontario Division of Mines, Preliminary Map P.844, scale 1:63 360.

Lumbers, S.B. 1975. Geology of the Burwash area, Districts of Nipissing, Parry Sound, and Sudbury; Ontario Division of Mines, Geological Report 116, 158p.

Lumbers, S.B. 1978. Geology of the Grenville Front Tectonic Zone in Ontario; *in* Toronto '78, Field Trips Guidebook, Geological Society of America-Geological Association of Canada-Minealogical Association of Canada, p.347-361.

Machado, N., David, J., Carignan, J., Zhang, Q. and Gariepy, C. 1991. Geochronologie U-Pb du territoire quebecois: fosses de l'Ungava et du Labrador, Province de Grenvile et sous-provinces de Pontiac et de l'Abitibi; report interne sourmis au Ministere de l'Energie et des Ressources du Quebec, service geologique du Nord-Ouest, vol. 2e, 48p.

Maniar, P.D. and Piccoli, P.M. 1989. Tectonic discrimination of granitoids; Geological Society of America, Bulletin, v. 101, p. 635-643.

McCrank, G.F.D., Kamineni, D.C., Ejeckam, R.B. and Sikorsky, R. 1989. Geology of the East Bull Lake gabbro-anorthosite pluton, Algoma District, Ontario; Canadian Journal of Earth Sciences, v.26, p.357-375.

Mehnert, K.R. 1971. Migmatites and the origin of granitic rocks; Elsevier, Amsterdam, 405p.

Meldrum, A., Abdel-Rahman, A.-F.M., Martin, R.F. and Wodicka, N. 1997. The nature, age and petrogenesis of the Cartier Batholith, northern flank of the Sudbury Structure, Ontario, Canada; Precambrian Research, v. 82, p. 265-285.

Meyer, W., Jerome, L.B., Gates, B.I. and Lacey, L.K. 1990. Sudbury Resident Geologist's area-1989; *in* Report of Activities, 1989, Regional and Resident Geologists, Ontario Geological Survey, Miscellanenous Paper 147, p.299-309.

Mortensen, J.K. and Card, K.D. 1993. U-Pb age constraints for the magmatic and tectonic evolution of the Pontiac Subprovince, Quebec; Canadian Journal of Earth Sciences, v.30, p.1970-1980.

Moser, D.E., Heaman, L.M., Krogh, T.E. and Hanes, J.A. 1996. Intracrustal extension of an Archean orogen revelaed using single-grain U-Pb zircon geochronology; Tectonics, v.15, p.1093-1109.

Murphy, E. 1999. Geology, metamorphism and geochemistry of Southern and Grenville Province rocks in the vicinity of the Grenville Front, Timmins Creek area, near Sudbury, Ontario; unpublished MSc thesis, Laurentian University, Sudbury, Ontario, 266p.

Murphy, E.I. 2001. Geology, metamorphism, and geochemistry of the Southern and Grenville province rocks in the vicinity of the Grenville Front, Timmins Creek area, near Sudbury, Ontario; Ontario Geological Survey, Open File Report 6041, 132p.

Murray, A. 1857. For the year 1856; *in* Geological Survey of Canada, Report of Progress for the years 1853-54-55-56, p.145-188.

NACSN. 1983. North American Stratigraphic Code, 1983; Association of Petroleum Geologists, Bulletin, v.67, p.841-875.

Newman, C.R. 1996. Report on 1995 Geological and Geochemical Exploration on the River Valley Project, Sudbury Mining District, Ontario (Project 3011), WMC International Limited; Sudbury Resident Geologist's office, Crerar Township, assessment file SP#0014, 23p.

Noble, S.R. and Lightfoot, P.C. 1992. U-Pb baddeleyite ages of the Kerns and Triangle Mountain intrusions, Nipissing diabase, Ontario; Canadian Journal of Earth Sciences, v.29, p.1424-1429.

Obradovich, T. 1999. 1999 OPAP final submission for the Loughrin project, Loughrin Township, Sudbury Mining Division; Sudbury Resident Geologist's office, Loughrin Township, assessment file SP#0006, 15p.

Ontario Geological Survey 1985a. Dana Township; Ontario Geological Survey, Data Inventory Folio 246, 16p.

Ontario Geological Survey 1985b. Loughrin Township; Geological Data Inventory Folio 247, 18p.

Ontario Geological Survey 1985c. Henry Township; Geological Data Inventory Folio 248, 16p.

Ontario Geological Survey 1985d. Crerar Township; Ontario Geological Survey, Data Inventory Folio 249, 16p.

Ontario Geological Survey 1987. Street Township; Geological Data Inventory Folio 340, 20p.

Ontario Geological Survey 1992a. Tectonic Assemblages of Ontario, explanatory notes and legend; Ontario Geological Survey, Map 2583.

Ontario Geological Survey 2002. Ontario airborne geophysical surveys, magnetic and eletromagnetic data, River Valley West area; Ontario Geophysical Data Set 1220.

Pan, Y., Fleet, M.E. and Heaman, L. 1998. Thermo-tectonic evolution of an Archean accretionary complex: U-Pb geochronological constraints on granulites from the Quetico subprovince, Ontario, Canada; Precambrian Research, v.92, p.117-128.

Parker, J.R. and Ayer, J.A. 1997. Distribution of evolved rhyolites in the Superior Province, Ontario; *in* Summary of Field Work and Other Activities, Ontario Geological Survey, Miscellaneous Paper 168, p.59-62.

Pearce, J.A., Harris, N.B.W. and Tindle, A.G. 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks; Journal of Petrology, v.25, p.956-983.

Pearson, W.J. 1959. Origin of the kyanite occurrences in the Wanapitei and Crocan Lake areas of Ontario; unpublished PhD thesis, Queen's University, Kingston, Ontario, 336p.

Peck, D.C., James, R. and Chubb, P. 1993. Geological environments for PGE-Cu-Ni Mineralization in the East Bull Lake Gabbro-Anorthosite Intrusion, Ontario; Exploration and Mining Geology, v. 2, p. 85-104.

Peck, D.C., James, R.S., Chubb, P.T. and Keays, R.R. 1995. Geology, metallogeny and petrogenensis of the East Bull Lake intrusion, Ontario; Ontario Geological Survey, Open File Report 5923, 117p.

Peck, D.C., Keays, R.R., James, R.S., Chubb, P.T. and Reeves, S.J. 2001. Controls on the formation of contact-type PGE mineralization in the East Bull Lake Intrusion; Economic Geology, v.96, p.559-581.

Percival, J.A. and Sullivan, R.W. 1988. Age Constraints on the Evolution of the Quetico Belt, Superior Province, Ontario; *in* Radiogenic Age and Isotopic Studies: Report 2; Geological Survey of Canada Paper 88-2, p.97-108.

Percival, J.A., Fountain, D.M. and Salisbury, M.H. 1992. Exposed crustal cross sections as windows on the lower crust; *in* Continental Lower Crust, edited by D.M. Fountain, R. Arculus and R.W. Kay, Elsevier, Amsterdam, p.317-362.

Positano, A.J. 1995. untitled report; Sudbury Resident Geologist's office, Henry Township, assessment file SP#0005, not paginated.

Prevec, S.A. 1993. An isotopic, geochemical and petrographic investigation of the genesis of early Proterozoic mafic intrusions and associated volcanics near Sudbury, Ontario; unpublished PhD thesis, University of Alberta, Edmonton, Alberta, 223p.

Prevec, S.A., James, R.S., Keays, R.R. and Vogel, D.C. 1995. Constraints on the genesis of Huronian magmatism in the Sudbury area from radiogenic isotopic and geochemical evidence; The Canadian Mineralogist, v.33, p.930-932.

Pye, E.G., Naldrett, A.J. and Giblin, P.E, eds. 1984. Geology and Ore Deposits of the Sudbury Structure; Ontario Geological Survey, Special Volume 1, 603p.

Ramsay, J.G. 1967. Folding and fracturing of rocks; McGraw—Hill, New York, 568p.

Ramsay, J.G. and Huber, M.L. 1987. The techniques of modern structural geology, volume 2: folds and fractures; Academic Press, New York, 700p.

Riller, U., Schwerdtner, W.M., Halls, H.C. and Card, K.D. 1999. Transpressive tectonism in the eastern Penokean orogen, Canada: consequences for Proterozoic crustal kinematics and continental fragmentation; Precambrian Research, v.93, p.51–70.

Robertson, J.A. 1976. Geology of the Massey area, districts of Algoma, Manitoulin and Sudbury; Ontario Department of Mines, Geological Report 136, 130p.

Robertson, J.A., Card, K.D. and Frarey, M.J. 1969. The federal-provincial committee on Huronian Stratigraphy, Progress Report; Ontario Geological Survey, Miscellaneous Paper 31, 26p.

Ross, J.S. 1959. An investigation of garnet from the Sudbury area, Ontario; Canada Department of Mines and Technical Surveys, Ottawa, Mines Branch, Investigative Report 59-65, 26p.

Rousell, D.H. and Trevisiol, D.D. 1988. Geology of the mineralized zone of the Wanapitei complex, Grenville Front, Ontario; Mineralium Deposita, v.23, p.138-149.

Schandl, E.S., Gorton, M.P. and Davis, D.W. 1994. Albitization at 1700+/-2 Ma in the Sudbury-Wanapitei Lake area, Ontario; Canadian Journal of Earth Sciences, v.31, p.597-607.

Smith, M.D. 2002. The timing and petrogenesis of the Creighton pluton, Ontario: an example of felsic magmatism associated with Matachewan igneous events; unpublished MSc thesis, University of Alberta, Edmonton, Alberta, 123p.

Steiger, R.H. and Wasserburg, G.J. 1969. Comparative U-Th-Pb systematics in 2.7X10e8 yr plutons of different geologic histories; Geochimica et Cosmochimica Acta, v.33, p.1212-1232.

Streckeisen, A. 1976. To each plutonic rock its proper name; Earth-Science Reviews, v.12, p. 1-33.

Sullivan, R.W. and Davidson, A. 1993. Monazite age of 1747 Ma confirms post-Penokean age of the Eden Lake Complex, Southern Province, Ontario; *in* Radiogenic Age and Isotopic Studies: Report 7, Geological Survey of Canada Paper 93-2, p.45-48.

Sun, S.S, and McDonough, W F. 1989. Chemical and isotopic systematics of oceanic basalts: Implications for mantle compositions and processes; *in* Magmatism in ocean basins: Geological Society of London, Special Publication 42, p.313-345.

Sawitzky, E. 1994. Geology report on the building stone project for John Brady; Sudbury Resident Geologist's office, Henry Township, assessment file SP#0004, 11p.

Tardiff, N. 2000. Regional distribution of platinum, palladium, gold, kimberlite indicator minerals and base metals in surficial sediments, River Valley area, northeastern Ontario; Ontario Geological Survey, Open File Report 6010, 106p.

Tardiff, N. and Crabtree, D. 2000. Kimberlite indicator minerals from till samples in the River Valley-Verner area, northeastern Ontario; Ontario Geological Survey, Open File Report 6040, 61p.

Taylor, S.R. and McClennan, S.M. 1985. The continental crust: its composition and evolution; Blackwell, New York, 312p.

Tettelaar, T. 2000. Petrography and geothermobarometry of variably metamorphosed and deformed leucogabbronorites of the River Valley intrusion, Grenville Province, Ontario; unpublished BSc thesis, Carleton University, Ottawa, Ontario, 59p.

Thomson, J.E. 1961. MacLennan and Scadding townships; Ontario Department of Mines, Geological Report 2, 34p.

Thomson, J.E. and Card, K.D. 1963. Kelly and Davis townships; Ontario Department of Mines, Geological Report 15, 20p.

Turner, F.J. 1981. Metamorphic petrology, mineralogical, field and tectonic aspects; 2nd edition. McGraw-Hill, New York, 524p.

Turner, F.J. and Weiss, L.E. 1963. Structural analysis of metamorphic tectonites; McGraw Hill, New York, 545p.

van Breemen, O. and Davidson, A. 1988. Northeast extension of Proterozoic terranes of mid-continental North America; Geological Society of America Bulletin, v.100, p.630-638.

Vander Voet, A.H.M. and Riddle, C. 1993. The analysis of geological materials, volume 1: a practical guide; Ontario Geological Survey, Miscellaneous Paper 149, 415p.

Vogel, D.C. 1996. The geology and geochemistry of the Agnew intrusion: implications for the petrogenesis of early Huronian mafic igneous rocks in central Ontario, Canada; unpublished PhD thesis, University of Melbourne, volume 1, 292p.

Vogel, D.C., James, R.S. and Keays, R.R. 1998. The early tectono-magmatic evolution of the Southern Province: implications from the Agnew Intrusion, central Ontario, Canada; Canadian Journal of Earth Sciences, v.35, p.854-870.

Vogel, D.C., Vuollo, J.I., Alapieti, T.T. and James, R.S. 1998. Tectonic, stratigraphic, and geochemical comparisons between ca. 2600-2440 Ma mafic igeneous events in the Canadian and Fennoscandian Shields; Precambrian Research, v.92, p.89-116.

Vogel, D.C., Keays, R.R., James, R.S. and Reeves, S.J. 1999. The geochemistry and petrogenesis of the Agnew Intrusion, Canada: a product of S-undersaturated, high-Al and low-Ti tholeiitic magmas; Journal of Petrology, v.40, p.423-450.

Vos, M.A., Smith, B.A. and Stevenato, R.J. 1981. Industrial minerals of the Sudbury area; Ontario Geological Survey, Open File Report 5329, 156p.

WIFCo and Dallaire, L.G. 1985. Production study to determine the feasibility of establishing a production plant in Sudbury, Ontario for the production of "Nipissing Granite"; Sudbury Resident Geologist's office, Henry Township, assessment file SP#0009, 53p.

Wodicka, N. and Card, K.D. 1995. Late Archean history of the Levack gneiss complex, southern Superior Province, Sudbury, Ontario: New evidence from U-Pb geochronology; Precambrian'95, Program with Abstracts, p.191.

Wood, P.C. 2000. Geological mapping report on the River Valley property - South Grid, October to December 1999, Crerar Township, Ontario, for Mustang Minerals Corporation; Sudbury Resident Geologist's office, Crerar Township, assessment file SP#0008, 31p.

Wood, P.C. 2002. Geological and geochemical report on the LG property, Loughrin, Davis and Henry townships, Ontario, Mustang Minerals Corporation; Sudbury Resident Geologist's office, Loughrin Township, assessment file SP#0016, 40p.

Young, G.M. 1983. Tectono-sedimentary history of early Proterozoic rocks of the northern Great Lakes area; *in* Early Proterozoic Geology of the Great Lakes Region, Geological Society of America, Memoir 160, p.15-32.

Zaleski, E., van Breemen, O. and Peterson, V.L. 1999. Geological evolution of the Manitouwadge greenstone belt and the Wawa-Quetico subprovince boundary, Superior Province, Ontario, constrained by U-Pb zircon dates of supracrustal and plutonic rocks; Canadian Journal of Earth Sciences, v.36, p.945-966.

Zolnai, A.I., Price, R.A. and Helmstaedt, H. 1984. Regional cross section of the Southern Province adjacent to Lake Huron, Ontario: implication for tectonic significance of the Murray Fault Zone; Canadian Journal of Earth Sciences, v.21, p.447-456.

Appendix 1.

Summary of Mineral Exploration Work in the Study Area.

Crerar Township.

Company or Individual	Location	Year of Work	Commodity	Work	Best Results	Comments	RGO File Number or Other Reference
G.C. Ferguson and McIntyre Porcupine Mines Lt.	central Crerar Township, Tomrose area	1956	Cu-Ni	Diamond drilling	0.46 and 1.30 wt % Cu	2 holes, 64 and 43 feet	Crerar 0010-A1
Falconbridge Nickel Mines Ltd.	central Crerar Township, Tomrose area	1964	Cu-Ni	Line cutting, ground magnetic and EM surveys			Crerar 0014-A1; 63.1342
Falconbridge Nickel Mines Ltd.	Lot 8, Conc. 4, Crerar Township	1965	Cu-Ni	Diamond drilling		1 hole, 101 feet	Crerar 0010-B1
Falconbridge Nickel Mines Ltd.	Lot 6, Conc. 5, Crerar Township	1965	Magnetite, Cu-Ni	Diamond drilling		2 holes, 235 and 198 feet	Crerar 0010-D1
Falconbridge Nickel Mines Ltd.	Lot 6, Conc. 5, Crerar Township	1965	Magnetite, Cu-Ni	Diamond drilling	3.3 and 6.6 wt.% magnetite	3 holes, 198, 149, 205 feet	Crerar 0012-A1
Tomrose Mines Ltd.	central Crerar Township, Tomrose area	1963 and 1964	Cu-Ni	Summary of previous work in prospectus		prospectus includes geological report by K.D. Card	Crerar 0015
Tomrose Mines Ltd.	central Crerar Township, Tomrose area	1965	Cu-Ni	Diamond drilling		2 holes, 104 and 270 feet	Crerar 0010-C1
Tomrose Mines Ltd.	central Crerar Township, Tomrose area	1966	Cu-Ni	Diamond drilling		1 hole, 442 feet	Crerar 0010-E1
Tomrose Mines Ltd.	central Crerar Township, Tomrose area	1963 and 1964	Cu-Ni	Diamond drilling, detailed geological map		13 holes, 106, 108, 496.5, 198, 303, 250, 233.5, 503, 503, 281, 300, 501, 625 feet	Crerar 0011
Tomrose Mines Ltd.	central Crerar Township, Tomrose area	1970	Cu-Ni	Geological mapping, ground magnetic and EM surveys, assays, trenching	0.15 wt. % Cu, 0.07 wt. % Ni		Crerar 0013; 63.3918
Azen Mines Ltd.	Lots 10, 11, Conc. 4 and 5, Crerar Township	1966	Magnetite, Cu-Ni	Ground magnetic survey			Crerar 0012-B1; 63.2083
A. Leblanc	central Crerar Township, Tomrose area	1989 and 1990	Cu-Ni-PGE	Stripping, diamond drilling, assay results	Hole 902, 120 ppb Pd, 180 ppb Pt, 1700 ppm Cu; Hole 903, 120 ppb Pd, 110 ppb Pt, 1600 ppm Cu	OPAP 90-472, 4 holes, 127, 208, 477, 502 feet	Crerar SP-001 and SP-002; 63.5976; W90007.00280, -00288, -00028; W9170.00033, -00034
A. Leblanc	central Crerar Township, Tomrose area	1994	Cu-Ni-PGE	Stripping, trenching, assay results	191 ppb Pt; 176 ppb Pd; 1340 ppm Cu, 559 ppm Ni;	OPAP 94-268; assay results also in WMC Ltd. report (Loughrin SP-004)	Crerar SP-003
WMC International Ltd.	eastern Street, Loughrin and Crerar townships	1995	Cu-Ni-PGE	Geological mapping, soil and rock assays		includes geological report by Newman (1996)	Crerar SP-004; 2.16588; W9670.00047
Mustang Minerals Corp.	central Crerar Township, Tomrose area	1999	Cu-Ni-PGE	Prospecting, detailed geological map and assay sampling	692 and 401 ppb, combined Au+Pd+Pt		Crerar SP-005; 2.19557; W9970.00225

Crerar Township, continued.

Company or Individual	Location	Year of Work	Commodity	Work	Best Results	Comments	RGO File Number or Other Reference
Mustang Minerals Corp.	Crerar Township, Tomrose area (South Grid)	1999	Cu-Ni-PGE	Line cutting, ground magnetic survey			Crerar SP-006; 2.20076; W0070.00024
Mustang Minerals Corp.	Crerar Township, Tomrose area (South Grid) and Dana-McWilliams townships (North Grid)	2000	Cu-Ni-PGE	Ground induced polarization survey			Crerar SP-007; 2.20381; W0070.00122
Mustang Minerals Corp.	Crerar Township, Tomrose area (South Grid)	1999	Cu-Ni-PGE	Geological mapping	448 assay samples, 2 samples at or near Tomrose had 2073 and 1105 ppb combined Au+Pd+Pt, average 55 ppb	16 whole rock samples, geological report	Crerar SP-008; 2.20091; W0070.00049
Mustang Minerals Corp.	Crerar Township, Tomrose area (South Grid) and Dana-McWilliams townships (North Grid)	2000 and 2001	Cu-Ni-PGE	Diamond drilling		66 holes totalling 17,001 m, 54 on North Grid, 12 on South Grid	Crerar SP-009; 2.23475; W0270.00757
Mustang Minerals Corp.	Crerar Township, Tomrose area (South Grid) and Regional Grids (Henry, Dana, Crerar townships)	2000	Cu-Ni-PGE	Geological mapping and geochemical results	682 assay samples from South Grid, 571 samples from the Regional Grids		Crerar SP-010; 2.23599; W0270.00878

Dana Township.

Company or Individual	Location	Year of Work	Commodity	Work	Best Results	Comments	RGO File Number or Other Reference
L. Larcher	eastern Dana, by Martin Lake	1976	Stone	Diamond drilling		7 holes, totalling 736 feet, quarry currently inactive	Dana 0010-A1
Quebec Metallurgical Ind. Ltd.	eastern Dana, by Martin Lake, Dana & McWilliams townships	1959	Stone	Stripping, geologival map		Quarry site currently inactive	Dana 0010-C1
Dana Black Granite Ltd.	Dana quarry	1998	Stone	Bridge repair, line cutting			Dana SP-002; 2.18905; W9870.00561
Rivale Industries Ltd.	Dana garnet property	1969	Garnet	Geological report			Dana 0010-D1; 63.3314
K.A. Davis	Dana garnet property	1969	Garnet	Stripping			Dana 0012-A1
Prodigy Resources Inc.	Dana garnet property	1998	Garnet	Geological mapping, prospecting			Dana SP-001; 2.18804; W9870.00528
Sharpmin Developments Inc.	Dana garnet property	1997, 1998	Garnet	Prospecting, trenching, blasting			Dana SP-003; 2.18958; W9870.00571
Kennco Ltd.	Dana (northwest corner), Janes, Kelly, Macbeth, Maclennan, McNish, Rathburn and Street townships	1968, 1969	Cu-Ni	Airborne magnetic and EM surveys		Little work in Dana Township	Dana 0011; 63.2445
J.P. Patrie	Dana North area	1969	Cu-Ni	Stripping, trenching			Dana 0012-A2
E.A. Gallo	central Crerar, southeastern Dana townships	1992	Cu-Ni-PGE	Prospecting		OPAP 92-074; -075; -076	Dana SP-007
L. Luhta	Dana and Pardo townships, South Pardo, Dana Lake, Azen Creek zones	1998	Cu-Ni-PGE	Geological mapping, prospecting, assay sampling	All values combined PGE = Pd+Pt+Rh. South Pardo, 0.27 g/tt Road zone 3.9 g/t; North zone 4.3 g/t, ave. 2.1; Trench zone 6.2 g/t, ave. 2.9; South 12.6 g/t, ave. 3.9; Azen zone 3.1 g/t, ave. 1.24	OPAP 98-387, -388, -389	Dana SP-005; 2.19680; W9970.00268
Mustang Minerals Corp.	Dana Township, Claim 1214628	1999	Cu-Ni-PGE	Geological mapping, prospecting, 30 assay samples	511 ppb Pt, 61 ppb Pd		Dana SP-004; 2.19671; W9970.00261
Mustang Minerals Corp.	Dana and McWillims townships, North Grid	1999	Cu-Ni-PGE	Geological mapping, prospecting, 83 assay samples, 6 whole rock geochemistry samples	Average 69 ppb combined Au+Pd+Pt; 2503 ppb best sample		Dana SP-008; 2.20092; W0070.00048
Mustang Minerals Corp.	Dana and McWilliams townships, North Grid	2001	Cu-Ni-PGE	Ground magnetic survey			Dana SP-017; 2.21860; W0170.30529

Dana Township. continued.

Company or Individual	Location	Year of Work	Commodity	Work	Best Results	Comments	RGO File Number or Other Reference
Mustang Minerals Corp.	McWilliams townships, North Grid	2001	Cu-Ni-PGE	Ground magnetic survey		Entirely in McWilliams Twp.	Dana SP-022; 2.22587; W0170.31257
Mustang Minerals Corp.	Regional Grid (Henry, Crerar townships), Southeast Grid (Dana and McWilliams townships); North Gird (Dana and McWilliams townships)	2001	Cu-Ni-PGE	Geological mapping and geochemical results	All values combined Au+Pd+Pt, in ppb. 282 assay samples from North Grid, (2375 combined, ave.=88); 217 from Southeast Grid (465 combined, ave.=36), 87 from Regional Grid (179 combined, ave.=29)		Crerar SP-026; 2.24282; W0270.01523
T.R.C. Management Inc.	eastern Dana Township	2000	Cu-Ni-PGE	Prospecting, ground VLF-EM survey, 61 assay samples			Dana SP-009; 2.20347; W0070.00102
Aquiline Resources Inc.	northern Crerar and Henry, southern Dana and Janes townships	2000	Cu-Ni-PGE	Ground induced polarization and magnetic surveys			Dana SP-012; 2.20799; W0070.00298
Aquiline Resources Inc.	southern Dana township ("Anaconda" Property)	2001	Cu-Ni-PGE	Geological mapping, prospecting, 138 channel samples	Assay results not available at time of filing		Dana SP-014; 2.20873; W0170.00020
Aquiline Resources Inc.	mainly in Pardo township, adjacent northwest corner of Dana Township	2001	Cu-Ni-PGE	Ground induced polarization and magnetic surveys			Dana SP-015; 2.20979; W0170.00058
Aquiline Resources Inc.	southern Dana township ("Anaconda" Property)	2001	Cu-Ni-PGE	Ground induced polarization and magnetic surveys			Dana SP-019; 2.22874; W0270.00179
Pacific North West Capital Corp.	Dana and Pardo townships, South Pardo, Dana Lake zones	1999	Cu-Ni-PGE	Geological mapping, line cutting, stripping, assay sampling	Too numerous to summarize		Dana SP-006; 2.19761; W9970.00300
Pacific North West Capital Corp.	Dana Lake and Azen Creek zones, Dana Township	1999	Cu-Ni-PGE	Ground induced polarization and magnetic surveys			Dana SP-010; 2.20317; W0070.00105
Pacific North West Capital Corp.	Dana Lake and Azen Creek zones, Dana Township	2000	Cu-Ni-PGE	Phase 1 diamond drilling program	Too numerous to summarize		Dana SP-011; 2.20591; W0070.00181
Pacific North West Capital Corp.	Dana Lake zone, Dana Township	2000	Cu-Ni-PGE	Phase 2 diamond drilling program	Too numerous to summarize		Dana SP-013; 2.21046; W0070.00073
Pacific North West Capital Corp.	Dana Lake and Lismer's Ridge zones, Dana Township	2000	Cu-Ni-PGE	Phase 3 diamond drilling program	Too numerous to summarize		Dana SP-021; 2.22916; W0270.00220
Pacific North West Capital Corp.	Dana Lake, Lismer's Ridge, MacDonald zones, Dana Township	2001	Cu-Ni-PGE	Phase 4 diamond drilling program	Too numerous to summarize		Dana SP-030; 2.24593; W0270.01820

Dana Township, continued.

Company or Individual	Location	Year of Work	Commodity	Work	Best Results	Comments	RGO File Number or Other Reference
Pacific North West Capital Corp.	Dana Lake and Lismer's Ridge zones, Dana Township	2002	Cu-Ni-PGE	Phase 5 diamond drilling program	Too numerous to summarize		Dana SP-029; 2.24604; W0270.01827
Pacific North West Capital Corp.	Dana Lake and Azen Creek zones, Dana Township	2000	Cu-Ni-PGE	Drillhole dipole and induced polarization surveys			Dana SP-023; 2.24255; W0270.01497
Pacific North West Capital Corp.	Azen Creek zone, Dana Township	2000	Cu-Ni-PGE	Ground induced polarization survey			Dana SP-027; 2.24250; W0270.01492
Pacific North West Capital Corp.	Dana Lake and Hen Lake zones, Dana Township	2000	Cu-Ni-PGE	Ground induced polarization and magnetic surveys			Dana SP-028; 2.24256; W0270.01498
Pacific North West Capital Corp.	Dana township	2000	Cu-Ni-PGE	Geological mapping, sampling of all main showings in River Valley intrusion in Dana Township	Too numerous to summarize	Summary of exploration activity to mid-2000.	Dana SP-025; 2.24281;W0270. 01521
Pacific North West Capital Corp.	Dana township, Thomson claims	2001	Cu-Ni-PGE	Geological mapping, assay sampling (64 samples)	0.99 g/t Pt and 0.56 g/t Pd		Dana SP-016; 2.21838; W0170.30507
Pacific North West Capital Corp.	Banshee Lake area and N contact of River Valley intrusion	2001	Cu-Ni-PGE	Geological mapping, assay sampling	Too numerous to summarize	Phase 3, surface exploration, geology maps	Dana SP-031 2.25758; W0370.0950
Pacific North West Capital Corp.	Dana township, claim S-1191268	2002	Cu-Ni-PGE	Geological mapping		Underlain only by country rocks to the River Valley intrusion	Dana SP-024 2.2435; W0270.01584

Henry Township.

Company or Individual	Location	Year of Work	Commodity	Work	Best Results	Comments	RGO File Number or Other Reference
F. Denomme	Northwest Henry	1977	Stone	Stripping			Henry-0010-A1
A. Leblanc	Northwest Henry	1977	Cu-Ni?	Stripping, tenching			Henry-0010-B1
A. Leblanc	Northwest Henry township	1983	Cu-Ni?	Diamond drilling		1 hole, 106 feet, some sulphide	Henry-0011-A1
A. Leblanc	Northwest Henry Township	1983	Cu-Ni?	Assay results on core from drilling	0.004 oz Au; 0.004 oz Ag		Henry-0011-B1; 2.6103
A. Leblanc	Northwest Henry	1984	Cu-Ni?	Diamond drilling		1 hole, 126 feet	Henry-012-A1
A. Leblanc	Northwest Henry	1986	Cu-Ni	Diamond drilling		1 hole, 112 feet	Henry SP-001
J.J. Positano	Henry Township, north quarry area	1992	Stone	Geological survey, includes 1 whole-rock analysis (Positano in Appendix 3)		Leucogabbro, East Bull Lake intrusive suite; includes 15 page geological report by Kirwan (1992)	Henry SP-002; 2.15066
J.J. Positano	Henry Township, north quarry area	1994	Stone	Stripping		Positano Granite; leucogabbro, East Bull Lake intrusive suite	Henry SP-003; 2.15749

Henry Township, continued.

Company or Individual	Location	Year of Work	Commodity	Work	Best Results	Comments	RGO File Number or Other Reference
J. Brady	Near Henry-Loughrin township boundary	1993, 1994	Stone	Geological survey, stripping, bulk sampling		Pink granite, black (Sudbury) diabase; includes report by Sawitzky (1994)	Henry SP-004; 2.15835; W9470.00236, -00237,- 00252
J.J. Positano	Henry Township, south quarry area	1995	Stone	Stripping, bulk sampling		Positano Granite; leucogabbro, East Bull Lake suite	Henry SP0-005; W9570.00109
J. Brady and M. Brady	Near Henry-Loughrin township boundary	1998	Stone	Stripping		Pink granite, black (Sudbury) diabase	Henry SP-006; 2.19200; W9970.00015
Warren Industrial Feldspar Co. Ltd. & L.G. Dallaire	"Darba" site, Henry Township	1985	Stone	Stripping, bulk sampling		Leucogabbro, East Bull Lake intrusive suite, includes report by WIFCo and Dallaire (1985)	Henry SP-009
F. Racicot and A. Leblanc	West-central Henry Township	2000	Cu-Ni-PGE	Geological mapping and sampling, 77 assay samples	1204 ppm Cu; 62 ppb Pt & 63 ppb Pd; 122 and 105 ppb Pd	Geological map	Henry SP-007; 2.20726; W0070.00236
Platinum Group Metals Ltd.	West-central Henry Township, including Dubeau, Positano, Brady and PGM Claims	2000	Cu-Ni-PGE	Geological mapping and geochemical sampling, including 92 rock and 142 B-horizon soil assay results	347 ppb Pt (546171E, 5161431N); disseminated sulphide (546064E, 5158929N)	Includes geological report by Hanych and Gore (2000)	Henry SP-008; 2.20798
Mustang Minerals Corp.	East (Dana Twp.), and Central Grids (east central Henry, west Crerar twps.)	2000	Cu-Ni-PGE	Line cutting, ground magnetic survey			Henry SP-010; 2.20806
Aquiline Resources Inc.	North central Henry and south central Janes twps.	2001	Cu-Ni-PGE	Ground magnetic survey			Henry SP-011; 2.20927; W0170.00042
Mustang Minerals Corp.	Central grid (east central Henry, west Crerar townships)	2001	Cu-Ni-PGE	Ground magnetic survey			Henry SP-012; 2.1858; W0170.30527
Mustang Minerals Corp.	Diagonal and Henry Grids (east central Henry, west Crerar townships)	2001	Cu-Ni-PGE	Ground induced polarization survey			Henry SP-013; 2.21862; W0170.30531
Mustang Minerals Corp.	Henry Grid (east central Henry township)	2001	Cu-Ni-PGE	Geological mapping, assay sampling	Best value, 365 ppb combined Au+Pd+Pt, 522 ppm Cu, 566 ppm Ni; verage 54 ppb combined, 83 ppm Cu, 33 ppm Ni.	Geology map, 1:7 500 scale.	Henry SP-014; 2.26195; W0370.01360

Loughrin Township.

Company or Individual	Location	Year of Work	Commodity	Work	Best Results	Comments	RGO File Number or Other Reference
Plexterre Mining Corp. Ltd.	Jones Lake area	1953	feldspar	Diamond drilling		4 holes 52, 80, 30, 17 feet	Loughrin-0010-A1
H.F. Wiemer	Page garnet area	1958	garnet?	Diamond drilling		1 hole, 104 feet	Loughrin-0010-B1
L. Jefferson	central Loughrin, lot 8, conc. 4	1951	unknown.	Diamond drilling	Intersected garnet gneiss, pegmatite, 6 holes were drilled in mafic gneiss ("gabbro")	16 holes, 260, 81, 50, 85, 63, 91, 82, 79, 26, 27, 36, 70, 30, 60, 82, 41, 82 feet	Loughrin-0010-C1
N. Chartrand		1973	unknown	Stripping			Loughrin-0010-E1
Lucky Creek Mining Co. Ltd.	Jones Lake area	1960	uranium, feldspar	Geological mapping, trenching	Pit #4, 13.4% U_3O_8, 11.9% U_3O_8.	Prospectus with short geological report	Loughrin-0011-A1
E.J. Plexman	Jones Lake area	1976	uranium	Trenching following a radiometric survey			Loughrin-0011-D1
Plexterre Mining Corp. Ltd.	southwest Davis, northwest Loughrin, southeast Scadding, northeast Street townships	1956, 1957	Cu-Au, feldspar-uranium	Geological mapping, ground EM survey		Prospectus with short geological report	Loughrin-0012
R. Stewart	Page garnet property	1990	Garnet	Mapping, sampling		OPAP 90-190; geological report and descriptions (Stewart 1991)	Loughrin SP-001; 2.14169; W9170.00099
E.A. Gallo	Loughrin (Jones-Halfway Lake area), Henry (west, north, southeast) and Crerar (central) townships	1993	Garnet	Prospecting		OPAP 93-151,see also Dana SP-007	Loughrin SP-003
J. Brady	Near border with Henry Twp.	1993	Stone	Stripping, trenching		Pink granite	Loughrin SP-002;W9470.000038
WMC International Ltd.	eastern Street, Loughrin and Crerar townships	1995	Cu-Ni	Geological mapping, sampling, assays, DIGHEM EM-VLF airborne survey	Best assays were from Tomrose occurrence in Crerar Township	Geological report by Newman (1996). Airborne survey released in 2002 (Ontario Geological Survey 2002)	Loughrin SP-004; 2.16415; W9670.00017, -00019
Z.L. Mandziuk	Detailed work in south central Loughrin township, some regional work in central Henry township	1999	Cu-Ni-PGE	Geological mapping, prospecting, ground magnetic and EM-VLF survey, diamond drilling	Drill hole, 74.5 m, 13 ppb Pd, 22 ppb Pt, 17 ppb Au	1 hole, 84.73 m, Burns Creek grid	Loughrin, SP-005; 2.20185; W0070.00063
T. Obradovich	northern Loughrin Township	1999	Cu-Ni-PGE	Geological mapping, ground VLF-EM and induced polarization surveys, 49 assay samples, 9 whole rock samples (see Appendix 3)	127 ppb combined Au+Pd+Pt in leucogabbro	OPAP	Loughrin SP-006; 2.20690; W0070.00220
T. Obradovich and Aquiline Resources Inc.	northern Loughrin Township	2000	Cu-Ni-PGE	Geological mapping, channel sampling, 313 rock channel samples for assay	252 ppb Pt and 249 ppb Pd. 506 ppm Cu		Loughrin SP-007; 2.20773; W0070.20773

Loughrin Township, continued.

Company or Individual	Location	Year of Work	Commodity	Work	Best Results	Comments	RGO File Number or Other Reference
T. Obradovich and Aquiline Resources Inc.	northern Loughrin Township	2002	Cu-Ni-PGE	ground induced polarization and magnetic surveys			Loughrin SP-015; 2.23745; W0270.01020
International Freegold Mineral Development Inc. & P.M. Dimmell	Southern Davis, northeast Loughrin townships	2000	Cu-Ni-PGE	Line cutting, grid prospecting, 18 grab samples for assay	243 ppb combined Au+Pd+Pt in leucogabbro (542670E, 5164785N), 413 ppm Cu+Ni in leucogabbro (544482E; 5164739N)		Loughrin SP-008; 2.20740
Mustang Minerals Corp.	LG property, northeast Loughrin, southeast Davis, northwest Henry townships	2001	Cu-Ni-PGE	ground magnetic survey			Loughrin SP-009; 2.21900; W0170.30560
Mustang Minerals Corp.	LG property, northeast Loughrin, southeast Davis, northwest Henry townships	2001	Cu-Ni-PGE	ground magnetic and induced polarization surveys			Loughrin SP-010; 2.22162; W0170.30790
Mustang Minerals Corp.	LG property, northeast Loughrin, southeast Davis, northwest Henry townships	2001	Cu-Ni-PGE	summary of mapping program 2000 to 2001	379 assay samples, highest combined Au+Pd+Pt = 559 ppb, average = 32 ppb, highest Cu 346 ppm, average 52 ppm, highest Ni = 865, average 30 ppm	Geological map and report, no evidence for contact style mineralization	Loughrin SP-016; 2.24185; W0270.01430
F. Racicot and Platinum Group Metals Ltd.	northeast Loughrin township, west of LG property	2001	Cu-Ni-PGE	Geological mapping and chip sampling	39 assay samples, 2 samples had combined Au+Pd+Pt >100ppb, highest was Au=20, Pd=30, Pt=73 ppb with 539 ppm Cu. Cu ranged from 4 to 539 ppm.		Loughrin SP-011; 2.22449; W0170.31116
Platinum Group Metals Ltd.	southeast Loughrin Township, Claim 1244239	2001	Cu-Ni-PGE	Geological mapping and chip sampling	2 assay samples	Geological report, Hanych (2002)	Loughrin SP-012; 2.23345; W0270.00622
Platinum Group Metals Ltd.	southeast Loughrin Township, Claim 1244242 and Lefrancois Land Patent	2002	Cu-Ni-PGE	Geological mapping and chip sampling	28 assay samples, Cu values of 3557, 4434 ppm adjacent a quartz vein, 7137 ppm Ni in a gabbronorite, 93 ppb Pt and 80 ppb Pd in gabbronorite		Loughrin SP-013; 2.23347; W0270.00632
Platinum Group Metals Ltd.	southeast Loughrin Township, Claim 1244238	2002	Cu-Ni-PGE	Geological mapping and chip sampling	1 assay sample of orthopyroxene hornblendite		Loughrin SP-014; 2.23346; W0270.00631

Street Township. Grenville Province only, for complete listing *see* Easton and Murphy (2002).

Company or Individual	Location	Year of Work	Commodity	Work	Best Results	Comments	RGO File Number or Other Reference
BP Resources Canada Limited	Street Twp. along the Wanapitei River	1987	Various	Aeromagnetic, EM and VLF-EM surveys.			Falconbridge-SP-003.
Bradley, D. (occurrence 1)	6 claim group in area of Potvin-Boulanger occurrences	1989, 1991	Au	Prospecting, assay sampling.	Best assays range from 0.04 to 0.09 g/t Au, one sample site analyzed 36 and 58 ppb Pt.		Street-SP-06, see also description in Kindle (1933), OP-89-70, OP91-514.
Brown, P. and Graham, R.	11 claims north of Timmins Creek	1983	Unknown	Ground magnetic and VLF-EM surveys.		Work on a mainly covered area.	Street-015.
Ecosource Garnet Inc. (occurrence 2b)	Central Street Twp., Central Zone	1999	Garnet	Diamond drilling	9 diamond-drill holes	Resource assessment, minimum 100 000 tonnes garnet	Street-SP-016
Emerald Isle Resources Inc., Stralak Resources Inc. (occurrence 2b, 2c)	Central Street Twp., North Zone, Central Zone	1993	Garnet	Stripping, diamond drilling.	All diamond-drill holes in zone 2 intersected 6-14 wide zone of garnet mineralization.		Street-SP-015, Street-SP-014, OMIP File#95-053.
Emerald Isle Resources Inc., Stralak Resources Inc.; Jarvis Resources (occurrence 2a)	Central Street Twp., South Zone	1991, 1993	Garnet	Stripping, access road construction, diamond drilling, bulk sampling, industrial mineral testing.			Street-SP-012, Street-SP-011, Street-SP-010, Street-SP-009-#2, Street-SP-008.
Gulf Minerals (driill hole A)	Timmins Creek area	1975-1976	U, Th	Diamond drilling.	9 diamond-drill holes.	Watt-McLean followed up on diamond-drill results.	Street-010-B1 (DD11).
International Freegold Inc.	Street metagabbro, southwest Street Twp.	1999-2000	Ni-Cu-PGE	Prospecting, ground VLF-EM and magnetics, assay data	Best assays, 244 ppb Pt, 543 ppb Pd, 344 ppb Au, 0.25% Cu, 0.10% Ni		Street-SP-021
Jamestown Explorations Incorporated	northeast of Boulanger-Potvin occurrence	1974	Unknown	No data on exploration program.			Street-011-B1.
Jerome, A.E. (occurrence 2a)	Central Street Twp.	1993	Garnet	Trenching, stripping			Street-SP-017.
McVittie, G. (occurrence 3)	West shore, Wanapitei River	Circa 1930	Au, Cu	Trenching, prospecting			Kindle (1933), Gates (1991)
New Arcadia Explorations Limited	Along Grenville Front, southwest Street Twp.	1984	Au, base metals	Geological mapping.			Dryden-020-A1.
Racicot, Frank	Street metagabbro, SW Street Twp.	2000	Ni-Cu-PGE	Prospecting, ground magnetics			Street-SP-020
St. Genevieve Resources Limited (occurrence 8)	Northeast corner, Street Twp.	1987	Au, Cu	Prospecting, geological mapping, ground magnetic and VLF-EM surveys.		Mostly in Scadding, follow-up on Au in humus anomalies in Scadding Twp. reported by Ateba Mines in 1981.	Scadding-SP-02; Ateba Mines data in Scadding-040, -052.

Street Township — continued.

Company or Individual	Location	Year of Work	Commodity	Work	Best Results	Comments	RGO File Number or Other Reference
Watt-McLean	Along Grenville Front throughout township	1984	Au, base metals	Geological mapping.			Street-014.
WMC International Limited	Southeast corner and east boundary of Street Twp.	1994-1996	Ni-Cu-PGM	Geological mapping, soil geochemistry aeromagnetic survey, rock assays.	Most assay work on samples from Emerald Isle Resources garnet property.	Survey area stretched from Street Twp to River Valley, only minor work on claims in Street Twp.	
W.R.3 (occurrence 8).	Timmins Creek area.	1992	Au	Prospecting, soil sampling.	350 ppb Au, 11 800 ppb Au in arsenopyrite-rich sample	Examined pit found in 1975 by Gulf Minerals, Watt McLean reported a sample from the pit assayed 10.9 g/t Au	Scadding SP-021, OP92-186, see also Kindle (1933), Gates (1991).

Abbreviations: EM = electromagnetic survey; g/t = grams per tonne; OPAP = Ontario Prospectors Assistance Program; Twp. = township; VLF-EM = very low frequency electromagnetic survey.

Appendix 2.

Listing of Geochemical Data on Country Rock Units in the Study Area.

Some of these data were previously published by Easton and Hrominchuk (1999, 2002) and Easton and Murphy (2002). All analyses by Geoscience Laboratories, Mines and Minerals Division.

Appendix 2. Listing of geochemical data on country rock units in the study area.

Sample No.	UTM 17, Easting	NAD83 Northing	Rock Type	SiO_2 wt.%	TiO_2 wt.%	Al_2O_3 wt.%	Fe_2O_3 wt.%	FeO wt.%	MnO wt.%	MgO wt.%	CaO wt.%	Na_2O wt.%
Felsites from Dana and Janes townships												
9C12A	Dressler	(1979)	granitoid	69.50	0.57	12.90	3.65	2.11	0.06	0.75	1.22	3.64
99RME-0022	553941	5166293	dacite	69.09	0.57	12.65	1.29	4.52	0.11	1.18	2.10	3.24
99RME-0061	554440	5168855	felsite	74.62	0.29	13.00	0.54	1.09	0.02	0.41	0.53	3.68
99RME-0067	554160	5170000	mylonite	68.42	0.55	12.61	1.84	3.51	0.06	1.88	1.01	3.06
99RME-0083	554055	5170613	felsite	68.46	0.61	13.03	2.31	3.37	0.07	1.77	0.92	4.38
99RME-0086	554149	5168611	felsite	61.81	1.04	12.64	4.47	6.73	0.20	1.16	3.57	4.11
99RME-0162	554310	5170383	felsite	68.05	0.53	12.52	2.59	2.82	0.13	0.69	1.78	3.77
99RME-0774	554390	5164743	granite, cuts RVI	68.25	0.70	13.13	4.10	2.34	0.08	0.42	1.98	3.51
02RME-1903	554106	5168600	felsite, U/Pb sample	67.82	0.62	12.89	6.76	NA	0.14	0.75	2.16	4.34
Dacite and related Geon 24 granitoid rocks from Street Township												
96RME-0124	532859	5162892	felsic volcanic	66.42	0.72	12.95	2.93	3.88	0.10	1.10	2.46	3.16
96RME-0606	532060	5162403	granite	67.59	0.70	12.55	2.18	4.20	0.10	0.60	3.32	3.25
Geon 24 and 23 granitoid rocks from Henry and Loughrin townships												
02RME-0006	544591	5153508	granodiorite dike cuts Crerar gneiss	70.82	0.42	14.50	2.28	NA	0.02	0.53	1.44	3.29
02RME-0013	544391	5159698	granodiorite	66.47	0.56	14.38	5.64	NA	0.12	0.91	2.64	4.23
02RME-0016	544353	5160492	granite, U/Pb sample	71.81	0.30	12.93	3.82	NA	0.07	0.18	1.26	4.09
02RME-0018	544410	5160881	granodiorite	66.68	0.71	13.33	7.28	NA	0.13	1.05	3.41	4.16
02RME-0295	551018	5161168	granite	73.38	0.31	13.34	2.31	NA	0.03	0.41	0.89	3.47
02RME-0558	541392	5157975	granite	70.88	0.34	12.43	5.49	NA	0.12	0.25	1.79	3.46
02RME-0682	550203	5159446	granite, altered?	73.70	0.30	12.67	3.89	NA	0.04	0.29	3.68	4.30
02RME-0683	549878	5159360	granite	72.94	0.34	13.60	2.51	NA	0.03	0.37	0.80	3.16
02RME-0704	535606	5156889	granite					NA				
Gowganda Formation rocks from Dana Township												
99RME-0079	553987	5171470	pebbly conglomerate	55.21	0.93	14.33	5.11	6.36	0.17	4.45	6.97	1.95
Mississagi Formation rocks from Dana Township												
99RME-0077	554425	5172568	feldspathic litharenite	79.16	0.22	10.43	1.51	1.10	0.02	1.23	0.04	0.94
Huronian Supergroup rocks from Henry and Loughrin townships												
02RME-0240	552126	5156496	quartzite	85.30	0.09	7.53	0.83	NA	0.01	0.31	1.12	0.93
86RLD-3002	491510	5146223	Serpent arkose	75.57	0.11	11.52	0.39	0.81	<0.01	1.40	0.63	4.79
02RME-0613	534066	5162515	matrrix, Ramsay Lake Fm.?	66.29	0.75	13.80	6.94	NA	0.10	1.99	2.45	2.98
Red Cedar Lake gneiss, Dana Township												
99RME-0448	563110	5158583	granodiorite	62.04	0.68	16.25	1.08	4.86	0.09	3.22	2.56	3.63
Pardo gneiss association, Dana and Pardo townships												
99RME-0025	560015	5174078	metawacke	63.76	0.58	15.62	2.09	3.11	0.06	3.08	3.23	3.63
99RME-0788	560015	5174078	granodiorite, felsic part of 99RME-0025	68.82	0.40	16.04	0.81	1.51	0.03	1.26	2.56	4.26
99RME-0789	559010	5173883	granodiorite	70.30	0.25	14.85	1.07	1.49	0.04	0.99	2.77	4.62
Mafic rocks within the Pardo gneiss association, Dana Township												
99RME-0139	561235	5169234	garnet amphibolite	49.01	1.31	14.52	4.22	8.93	0.23	6.62	9.97	0.88
Mafic dikes within the Crerar gneiss association, Henry and Loughrin townships												
02RME-0004	544591	5153508	mafic dike	47.04	1.23	10.05	14.52	NA	0.21	11.59	10.82	1.55
02RME-0005	544591	5153508	mafic dike	52.38	0.56	13.72	10.24	NA	0.17	8.70	10.16	2.85
02RME-0257	552152	5160246	mafic dike	49.50	0.70	4.53	13.58	NA	0.22	18.82	10.78	0.94

NA = not analyzed. Abbreviations: CIA = chemical index of alteration, PGE = total Au+Pd+Pt for the sample. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 2. Listing of geochemical data on country rock units in the study area — continued.

Sample No.	K_2O wt.%	P_2O_5 wt.%	CO_2 Wt.%	S wt.%	LOI wt.%	Total wt.%	Mg-no.	CIA No.	Cr ppm	Ni ppm	Co ppm	Cu ppm	Sc ppm	V ppm	Au ppb	Pd ppb	Pt ppb	PGE ppb
Felsites from Dana and Janes townships																		
9C12A	3.95	0.18	0.12	0.02	0.79	99.32	19.9	59.7	10	16	7	49	NA	NA	NA	NA	NA	
99RME-0022	3.49	0.21	0.45	0.01	1.02	99.47	27.0	60.2	33	13	10	11	9	21	<5	<8	<8	
99RME-0061	5.33	0.09	0.06	<0.01	0.63	100.23	31.7	57.8	58	8	<5	6	4	22	<5	<8	<8	
99RME-0067	5.41	0.19	0.12	<0.01	0.97	99.51	39.3	57.4	16	8	9	10	9	17	<5	<8	<8	
99RME-0083	3.90	0.22	0.09	<0.01	0.79	99.83	36.6	58.9	45	8	8	7	10	18	<5	<8	<8	
99RME-0086	2.87	0.45	0.07	0.02	0.44	99.49	16.1	54.7	26	10	20	24	15	17	<5	<8	<8	
99RME-0162	4.41	0.16	0.22	0.01	0.62	98.07	19.3	56.2	52	8	9	20	9	12	<5	<8	<8	
99RME-0774	4.83	0.10	0.05	<0.01	0.33	99.77	11.0	56.1	15	8	6	12	11	13	<5	<8	<8	
02RME-1903	3.87	0.22	0.10	<0.01	0.40	99.97	18.0	55.7	10	6	13	17	10	9	<6	<2	<1	
Dacite and related Geon 24 granitoid rocks from Street Township																		
96RME-0124	3.57	0.15	0.15	0.12	1.40	98.84	23.1	58.9	38	16	9	9	11	28	<3	<10	<5	
96RME-0606	3.60	0.11	0.38	<0.01	0.86	99.06	14.8	56.2	4	7	6	5	10	10	NA	NA	NA	
Geon 24 and 23 granitoid rocks from Henry and Loughrin townships																		
02RME-0006	5.98	0.09	0.07	0.01	0.33	99.71	31.1	57.7	8	<2	<12	20	1	34	<6	<2	<1	
02RME-0013	4.25	0.20	0.34	<0.01	0.58	99.98	24.3	57.2	5	<2	<12	22	8	27	<6	<2	<1	
02RME-0016	5.01	0.05	0.10	0.01	0.13	99.66	8.2	55.8	11	2	<12	6	5	9	<6	<2	<1	
02RME-0018	2.98	0.21	0.08	<0.01	0.22	100.16	22.2	56.0	16	4	27	<2	10	38	39	<2	<1	39
02RME-0295	5.40	0.09	0.21	<0.01	0.54	100.17	26.0	58.3	19	4	6	6	4	13	<6	<2	<1	
02RME-0558	4.64	0.07	0.08	<0.01	0.18	99.65	8.3	55.9	13	6	4	4	6	<1	<6	<2	<1	
02RME-0682	0.69	0.05	0.10	0.01	0.29	99.91	12.9	59.7	14	3	5	8	5	1	<6	<2	<1	
02RME-0683	5.54	0.09	0.11	<0.01	0.56	99.94	22.6	59.2	15	3	6	9	4	13	<6	<2	<1	
02RME-0704			0.05	<0.01					<4	6	2	3	7	5				
Gowganda Formation rocks from Dana Township																		
99RME-0079	2.38	0.13	0.10	0.02	1.57	99.56	42.0	56.1	70	56	41	184	26	234	<5	17	17	34
Mississagi Formation rocks from Dana Township																		
99RME-0077	4.27	0.03	0.07	0.23	2.00	100.95	47.2	66.8	172	24	7	18	5	45	<5	<8	<8	
Huronian Supergroup rocks from Henry and Loughrin townships																		
02RME-0240	2.31	0.02	0.43	<0.01	0.99	99.44	43.6	65.7	31	<2	<12	<2	<1	30	<6	<2	<1	
86RLD-3002	1.88	<0.01	0.71	<0.01	1.31	97.21	68.2	63.6	34	15	<5	5	2	18	NA	NA	NA	
02RME-0613	3.83	0.17	0.64	0.23	0.94	100.47	36.2	61.6	64	33	26	64	12	82	<6	<2	2	2
Red Cedar Lake gneiss, Dana Township																		
99RME-0448	3.25	0.06	0.16	0.15	0.85	98.57	49.6	63.7	213	91	22	43	13	124	<5	<8	<8	
Pardo gneiss association, Dana and Pardo townships																		
99RME-0025	2.97	0.13	0.12	0.09	1.18	99.44	52.4	61.7	183	64	19	28	9	120	<5	<8	<8	
99RME-0788	3.41	0.13	0.10	0.02	0.82	100.05	50.1	61.3	68	24	5	16	4	40	<5	<8	<8	
99RME-0789	1.84	0.06	0.03	<0.01	0.73	99.01	41.8	61.7	37	12	5	<5	4	28	<5	<8	<8	
Mafic rocks within the Pardo gneiss association, Dana Township																		
99RME-0139	2.31	0.15	<0.03	0.11	1.32	99.47	48.1	52.5	119	89	49	172	34	319	<5	13	12	25
Mafic dikes within the Crerar gneiss association, Henry and Loughrin townships																		
02RME-0004	1.35	0.13	0.09	0.19	0.84	99.52	61.2	42.4	1320	357	82	152	31	268	40	<2	7	47
02RME-0005	1.08	0.06	0.50	0.01	1.12	101.08	62.7	50.2	609	166	57	2	31	175	<6	<2	2.7	3
02RME-0257	0.11	0.06	0.10	<0.01	1.02	100.33	73.3	26.8	1569	959	94	74	19	164	10	<2	<1	10

NA = not analyzed. Abbreviations: CIA = chemical index of alteration, PGE = total Au+Pd+Pt for the sample. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 2. Listing of geochemical data on country rock units in the study area — continued.

Sample No.	Pb ppm	Zn ppm	Mo ppm	W ppm	Sn ppm	As ppm	Be ppm	Rb ppm	Cs ppm	Ba ppm	Sr ppm	Ga ppm	Li ppm	Ta ppm	Nb ppm	Hf ppm	Zr ppm	Y ppm	Zr/Y
Felsites from Dana and Janes townships																			
9C12A	10	66	<8	<40	NA	NA	NA	NA	NA	600	NA	NA	NA	NA	NA	NA	NA	NA	NA
99RME-0022	9	98	<8	<40	NA	NA	<3	80.0	0.55	918	179	NA	NA	0.90	11.3	5.38	202.0	35.0	6
99RME-0061	13	33	<8	<40	NA	NA	<3	164.0	0.52	494	50	NA	NA	1.18	12.9	4.67	156.0	17.0	9
99RME-0067	6	78	12	<40	NA	NA	<3	131.4	1.95	1320	72	NA	NA	1.05	15.4	9.45	280.7	34.2	8
99RME-0083	5	87	<8	<40	NA	NA	<3	108.0	1.36	1356	78	NA	NA	1.04	13.2	8.31	315.0	46.0	7
99RME-0086	14	173	<8	<40	NA	NA	<3	97.0	1.53	771	173	NA	NA	0.86	12.1	7.60	286.0	56.0	5
99RME-0162	16	127	<8	<40	NA	NA	<3	111.0	0.96	1180	178	NA	NA	1.00	14.4	8.99	354.0	48.0	7
99RME-0774	19	71	<8	<40	NA	NA	<3	132.2	0.32	1211	190	NA	NA	0.90	18.1	11.56	382.5	54.4	7
02RME-1903	20	122	NA	NA	<5	<2	2	107.0	1.03	843	115	18	13	1.03	14.5	8.74	299.0	45.0	7
Dacite and related Geon 24 granitoid rocks from Street Township																			
96RME-0124	23	90	<8	<40	NA	NA	<3	96.0	NA	1070	160	NA	NA	NA	23.0	NA	434.0	69.0	6
96RME-0606	17	42	<8	<40	NA	NA	<3	90.0	NA	970	160	NA	NA	1.50	26.0	6.20	440.0	67.0	7
Geon 24 and 23 granitoid rocks from Henry and Loughrin townships																			
02RME-0006	21	44	<8	<2	<5	3	0.9	145.0	1.79	1750	426	16	NA	0.78	11.0	8.50	377.0	22.4	17
02RME-0013	22	110	<8	<2	<5	3	1.8	165.0	1.93	911	231	16	NA	0.92	13.7	8.20	320.0	40.0	8
02RME-0016	21	103	<8	<2	<5	4	2.0	164.0	1.26	1180	100	16	NA	1.26	22.3	14.10	579.0	81.6	7
02RME-0018	20	119	<8	<2	<5	4	1.6	82.0	0.91	799	292	16	NA	0.95	12.7	7.50	293.0	36.7	8
02RME-0295	<5	23	<8	<2	<5	<2	1.7	209.0	1.38	773	103	17	14	0.98	16.6	7.46	278.0	37.0	8
02RME-0558	23	153	<8	<2	5	<2	2.3	144.0	1.48	1318	113	20	29	1.98	34.7	21.58	682.0	97.0	7
02RME-0682	7	19	<8	<2	6	<2	1.7	10.0	0.15	70	336	20	21	1.52	25.7	11.34	526.0	69.0	8
02RME-0683	9	36	<8	<2	<5	<2	1.5	214.5	1.45	759	84	16	13	0.66	13.9	8.17	294.0	33.0	9
02RME-0704	19	183	<8	<2	5	<1	2.9	130.0		1460	108	21			32.0		658.0	101.0	7
Gowganda Formation rocks from Dana Township																			
99RME-0079	21	135	8	<40	NA	NA	<3	77.0	3.02	1114	513	NA	NA	0.49	5.2	3.16	116.0	25.0	5
Mississagi Formation rocks from Dana Township																			
99RME-0077	8	26	<8	<40	NA	NA	<3	132.0	3.10	995	67	NA	NA	0.42	3.5	2.05	72.0	3.0	24
Huronian Supergroup rocks from Henry and Loughrin townships																			
02RME-0240	<5	52	<8	<2	<5	<2	0.3	70.9	0.26	362	60	8	NA	<0.20	1.8	1.40	50.1	2.9	17
86RLD-3002	9	10	9	<35	NA	<6	<3	45.0	0.84	480	190	NA	NA	0.16	1.6	1.00	48.0	9.0	5
02RME-0613	29	142	NA	NA	<5	<2	1	98.0	2.11	1069	141	19	11	1.01	13.6	7.18	235.0	26.0	9
Red Cedar Lake gneiss, Dana Township																			
99RME-0448	18	104	17	<40	NA	NA	<3	142.9	3.59	606	490	NA	NA	0.86	14.9	5.83	186.3	11.5	16
Pardo gneiss association, Dana and Pardo townships																			
99RME-0025	19	94	16	<40	NA	NA	<3	138.9	3.30	670	464	NA	NA	0.54	6.8	3.94	117.1	8.0	15
99RME-0788	17	48	12	<40	NA	NA	<3	127.8	2.05	770	499	NA	NA	0.60	10.0	3.35	103.8	8.4	12
99RME-0789	19	51	11	<40	NA	NA	<3	113.2	1.98	335	435	NA	NA	0.57	7.1	5.88	174.1	11.1	16
Mafic rocks within the Pardo gneiss association, Dana Township																			
99RME-0139	16	128	<8	<40	NA	NA	<3	121.0	3.24	212	182	NA	NA	0.44	5.5	1.67	1.7	62.0	31
Mafic dikes within the Crerar gneiss association, Henry and Loughrin townships																			
02RME-0004	21	148	<8	<2	<5	<2	0.5	25	0.40	1673	123	18	NA	0.46	5.9	1.70	54.4	19.2	3
02RME-0005	22	95	<8	<2	<5	<2	0.5	13	0.12	830	130	20	NA	0.46	4.9	2.64	101.1	20.9	5
02RME-0257	10	132	<8	<2	<5	<2	0.7		0.09	942	74	19	NA	0.49	6.5	1.70	60.4	12.3	5

NA = not analyzed. Abbreviations: CIA = chemical index of alteration, PGE = total Au+Pd+Pt for the sample. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 2. Listing of geochemical data on country rock units in the study area — continued.

Sample No.	Th ppm	U ppm	La ppm	Ce ppm	Pr ppm	Nd ppm	Sm ppm	Eu ppm	Gd ppm	Tb ppm	Dy ppm	Ho ppm	Er ppm	Tm ppm	Yb ppm	Lu ppm	Total REE
Felsites from Dana and Janes townships																	
9C12A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
99RME-0022	11.37	3.01	43.36	110.10	10.64	41.74	7.86	1.81	7.03	1.09	6.29	1.25	3.45	0.58	3.47	0.49	239.2
99RME-0061	17.05	4.12	31.35	100.20	7.61	26.72	4.89	0.46	3.96	0.61	3.14	0.58	1.60	0.29	1.49	0.23	183.1
99RME-0067	15.77	3.67	52.06	97.83	13.76	49.83	7.97	1.56	6.28	1.03	6.02	1.43	4.54	0.72	4.74	0.81	248.6
99RME-0083	14.25	3.41	121.49	>250.00	23.99	83.94	11.59	2.79	10.06	1.44	8.04	1.57	4.30	0.74	4.18	0.64	274.8
99RME-0086	11.23	2.33	51.37	118.55	12.56	51.18	10.60	2.38	10.17	1.59	9.60	1.99	5.33	0.93	5.39	0.82	282.5
99RME-0162	13.96	2.90	54.39	148.62	13.19	50.90	9.92	2.01	8.88	1.41	8.27	1.67	4.76	0.84	4.94	0.76	310.6
99RME-0774	20.30	1.98	64.18	118.90	18.41	66.30	12.65	2.02	10.04	1.63	9.46	2.22	6.23	0.92	5.70	0.92	319.6
02RME-1903	14.16	3.21	58.73	104.64	14.01	51.57	9.83	2.29	9.36	1.42	8.29	1.79	4.96	0.76	4.56	0.73	272.9
Dacite and related Geon 24 granitoid rocks from Street Township																	
96RME-0124	18.00	0.00	59.59	146.86	15.57	58.67	12.06	2.30	11.32	1.88	11.51	2.48	7.37	1.10	6.77	0.99	338.5
96RME-0606	19.00	3.50	67.00	170.00	16.00	60.00	12.00	2.50	12.00	2.00	11.00	2.40	6.90	0.98	6.30	0.95	370.0
Geon 24 and 23 granitoid rocks from Henry and Loughrin townships																	
02RME-0006	16.40	1.30	89.20	162.00	18.50	61.60	9.57	1.60	6.12	0.78	3.86	0.70	1.87	0.24	1.68	0.20	357.9
02RME-0013	16.30	3.01	52.70	105.00	13.00	48.60	9.49	2.02	8.36	1.23	7.07	1.44	3.99	0.58	3.89	0.56	257.9
02RME-0016	19.40	2.39	66.50	137.00	17.00	63.80	13.20	2.08	12.80	2.16	13.60	2.90	8.69	1.35	8.80	1.32	351.2
02RME-0018	11.60	2.73	48.20	96.40	12.00	46.10	8.92	2.11	7.98	1.15	6.74	1.28	3.68	0.50	3.55	0.53	239.1
02RME-0295	26.47	2.09	69.88	124.77	17.59	61.32	11.08	1.37	9.01	1.38	7.62	1.56	4.22	0.62	3.62	0.56	314.6
02RME-0558	15.39	2.70	56.49	117.59	13.25	51.64	12.41	2.98	14.72	2.73	17.78	4.09	12.00	1.90	11.99	1.91	321.5
02RME-0682	19.20	2.76	69.09	132.39	17.58	65.49	13.07	2.58	13.05	2.20	13.71	3.11	9.30	1.44	9.12	1.43	353.6
02RME-0683	25.23	2.65	51.38	102.02	12.93	45.61	8.25	1.10	6.99	1.11	6.23	1.36	3.96	0.61	3.71	0.58	245.8
02RME-0704	14.00																
Gowganda Formation rocks from Dana Township																	
99RME-0079	5.16	2.03	20.64	45.27	4.97	20.32	4.13	1.29	4.06	0.70	4.16	0.86	2.47	0.42	2.50	0.39	112.2
Mississagi Formation rocks from Dana Township																	
99RMF-0077	3.89	1.56	3.90	10.48	0.70	2.23	0.36	0.31	0.32	0.06	0.41	0.10	0.34	0.06	0.44	0.07	19.8
Huronian Supergroup rocks from Henry and Loughrin townships																	
02RME-0240	4.57	0.28	14.70	26.40	3.10	10.20	1.68	0.28	1.00	0.11	0.58	0.09	0.19	0.01	0.15	0.01	58.5
86RLD-3002	2.00	0.71	30.00	64.00	7.90	29.00	4.20	0.82	2.80	0.32	1.20	0.19	0.53	0.06	0.50	0.08	141.6
02RME-0613	12.32	2.85	34.96	70.09	8.95	32.30	6.29	1.73	5.60	0.88	5.35	1.11	3.20	0.49	3.16	0.49	174.6
Red Cedar Lake gneiss, Dana Township																	
99RME-0448	11.74	1.17	36.81	66.55	8.65	29.22	4.50	0.92	2.72	0.34	2.02	0.38	1.21	0.18	1.23	0.19	154.9
Pardo gneiss association, Dana and Pardo townships																	
99RME-0025	11.82	2.54	16.94	32.74	4.14	14.69	2.56	0.73	1.96	0.27	1.50	0.29	0.85	0.11	0.83	0.13	77.7
99RME-0788	3.18	0.71	5.96	14.68	1.79	7.12	1.74	0.92	1.52	0.24	1.33	0.28	0.78	0.08	0.64	0.08	37.2
99RME-0789	16.65	0.66	33.43	64.54	8.14	25.95	4.58	0.76	3.08	0.42	2.17	0.39	1.01	0.10	0.65	0.09	145.3
Mafic rocks within the Pardo gneiss association, Dana Township																	
99RME-0139	2.30	0.59	11.56	23.26	3.24	14.68	3.76	1.19	4.21	0.74	4.78	1.06	2.92	0.49	3.02	0.46	75.4
Mafic dikes within the Crerar gneiss association, Henry and Loughrin townships																	
02RME-0004	0.68	0.16	12.15	28.96	4.22	18.33	4.36	1.58	4.60	0.67	3.77	0.77	1.85	0.26	1.57	0.24	83.3
02RME-0005	5.50	1.03	16.08	30.34	3.78	14.14	3.18	0.91	3.39	0.57	3.52	0.81	2.20	0.34	2.22	0.37	81.9
02RME-0257	1.33	0.36	9.17	23.38	3.29	13.68	3.03	0.88	2.81	0.45	2.42	0.52	1.28	0.18	1.06	0.17	62.3

NA = not analyzed. Abbreviations: CIA = chemical index of alteration, PGE = total Au+Pd+Pt for the sample. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 2. Listing of geochemical data on country rock units in the study area — continued.

Sample No.	UTM 17, Easting	NAD83 Northing	Rock Type	SiO_2 wt.%	TiO_2 wt.%	Al_2O_3 wt.%	Fe_2O_3 wt.%	FeO wt.%	MnO wt.%	MgO wt.%	CaO wt.%	Na_2O wt.%
Mafic gneiss in the Street gneiss association, Henry, Loughrin and Street townships												
02RME-0466	539522	5157621	mafic gneiss, unit 4	53.36	0.63	15.57	10.74	NA	0.18	6.30	10.30	2.23
96RME-0456	527500	5154633	mafic gneiss, unit 4	55.57	0.94	13.86	2.47	9.50	0.20	3.47	7.74	2.53
96RME-0458	527210	5154593	mafic gneiss, unit 4	52.25	0.61	14.81	1.76	7.70	0.17	6.53	9.71	2.52
96RME-0459	527210	5154593	mafic gneiss, unit 4	55.37	0.52	14.61	1.52	6.60	0.14	5.72	9.18	2.68
Crerar gneiss association												
99RME-0184	562000	5157073	granodiorite, U/Pb site	58.69	0.70	18.86	1.67	3.24	0.09	2.17	4.15	5.14
99RME-0189	560310	5159123	granodiorite	63.71	0.60	16.16	1.63	2.90	0.07	2.02	3.44	4.50
99RME-0430	556010	5155323	granodiorite	68.89	0.34	15.93	1.03	1.67	0.03	1.20	3.35	5.11
99RME-0375	558780	5159433	biotite diorite	55.29	1.57	13.80	3.36	10.02	0.17	3.35	6.73	2.58
Late graniroid rocks (Neoarchean?)												
02RME-1902	559857	5167290	granite, U/Pb site	69.70	0.34	15.12	2.84	NA	0.04	0.68	1.71	4.45
99RME-2139	559785	5167228	granite	72.26	0.10	15.21	0.16	0.44	0.01	0.28	1.14	4.02
99RME-0322	556210	5159383	quartzite	73.34	0.06	14.49	0.13	0.29	0.01	0.27	1.77	5.00
99RME-0578	559272	5160814	quartzite	62.74	0.04	21.70	0.13	0.23	<0.01	0.13	3.39	9.07
99RME-0592	563510	5168958	syenite	71.53	0.17	14.42	0.71	0.61	0.01	0.47	1.58	3.72
99RME-0596	563030	5168883	syenite	62.64	1.02	16.71	2.31	2.51	0.05	1.36	3.14	4.62
99RME-0326	559430	5159883	granite	71.40	0.21	15.36	0.36	0.72	0.01	0.50	0.77	4.47
02RME-0070	534975	5163365	feldspar	65.22	0.01	18.73	0.02	NA	<0.01	0.02	0.05	2.26
02RME-0071	534891	5163346	feldspar	65.09	0.01	18.84	0.01	NA	<0.01	0.03	0.04	1.98
Nipissing intrusive suite (ca. 2220 Ma)												
99RME-0023	554673	5168571	Nipissing gabbro	51.26	0.38	11.88	1.45	7.14	0.18	12.25	13.32	1.12
99RME-0024	554588	5168530	Nipissing gabbro	50.28	0.36	13.14	1.29	6.72	0.16	11.67	12.81	1.15
02RME-0069	535121	5163293	quartz diorite	60.57	1.05	13.36	11.00	NA	0.17	2.14	4.98	3.52
02RME-0152	534885	5156722	Nipissing gabbro	55.23	0.65	15.34	9.80	NA	0.16	5.40	9.53	2.31
Matachewan dike swarm (ca. 2446 Ma)												
99RME-0031	559913	5174428	cuts Pardo gneiss	50.36	1.15	14.07	3.09	11.11	0.22	5.89	10.02	1.97
99RME-0355	554950	5169473	mafic mass	49.80	0.91	16.20	2.53	9.44	0.19	5.82	11.08	2.00
99RME-2118	556604	5166762	dike cuts RVI	50.34	1.20	14.78	3.18	10.54	0.20	5.62	9.82	2.65
99RME-4008	556033	5166762	dike cuts RVI	50.64	1.20	14.70	2.84	10.95	0.22	5.65	10.04	1.81
Matachewan	Vogel et	al. (1999)	ave. of 16 dikes	50.26	1.33	14.40	14.28	NA	0.22	6.04	9.73	2.74
Sudbury dike swarm (ca. 1238 Ma)												
99RME-0080	553935	5171342	cuts Gowganda Fm.	45.51	2.77	16.58	2.82	12.00	0.19	5.78	7.83	3.47
99RME-0137	561255	5169258	cuts Pardo gneiss	45.50	2.97	15.60	2.16	13.60	0.23	5.21	8.21	3.26
99RME-0237	556510	5171868	cuts Pardo gneiss	46.05	2.50	16.26	1.94	13.10	0.21	6.06	8.38	3.33
99RME-0325	559490	5159223	cuts Crerar gneiss	44.88	3.28	16.25	2.34	13.81	0.21	5.96	7.82	2.92
99RME-0337	556100	5169743	cuts RVI	45.53	2.96	16.61	1.67	13.72	0.20	5.95	7.76	3.49
99RME-2123	556898	5165693	gabbro	41.35	3.10	18.97	8.13	11.88	0.16	3.28	9.82	1.71
99RME-2178	558499	5166628	fgr gabbro	45.58	3.28	16.07	1.29	14.29	0.20	5.16	7.81	3.38
99RME-2223	560650	5163983	fgr gabbro	42.19	2.96	12.23	2.55	18.82	0.26	11.24	5.60	2.71
99RME-2256	560135	5164658	fgr gabbro	45.75	2.87	16.05	3.00	12.44	0.20	5.81	7.99	3.39
02RME-0014	544433	5160554	fgr gabbro	46.40	2.31	16.57	15.18	NA	0.20	6.83	8.88	3.48
02RME-0255	552090	5159950	fgr gabbro	45.39	3.09	16.17	16.98	NA	0.22	5.58	8.06	2.82
Breccia body (possibly related to Sudbury dike swarm)												
02RME-0030	545031	5163527	diatreme matrix	54.72	2.25	14.87	12.82	NA	0.17	4.29	5.58	2.61
Grenville dike swarm (ca. 590 Ma)												
99RME-0138	561220	5169300	chill margin of dike	49.65	2.05	13.59	1.00	14.59	0.24	6.02	9.90	2.20
02RME-0097	549405	5162031	core of dike	48.48	1.82	16.73	14.71	NA	0.20	4.90	10.34	2.77

NA = not analyzed. Abbreviations: CIA = chemical index of alteration, fgr = fine-grained, PGE = total Au+Pd+Pt for the sample. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 2. Listing of geochemical data on country rock units in the study area — continued.

Sample No.	K_2O wt.%	P_2O_5 wt.%	CO_2 wt.%	S wt.%	LOI wt.%	Total wt.%	Mg-no.	CIA no.	Cr ppm	Ni ppm	Co ppm	Cu ppm	Sc ppm	V ppm	Au ppb	Pd ppb	Pt ppb	PGE ppb
Mafic gneiss in the Street gneiss association, Henry, Loughrin and Street townships																		
02RME-0466	1.11	0.08	0.07	0.01	0.48	100.99	53.7	53.4	105	102	50	67	27	153	<6	5	3	8
96RME-0456	1.52	0.08	0.08	<0.01	0.50	98.38	34.5	54.2	10	40	40	130	27	200	NA	<10	10	10
96RME-0458	1.13	0.04	0.08	<0.01	1.31	98.54	55.6	52.7	180	110	40	51	27	160	NA	<10	<5	
96RME-0459	1.05	0.02	0.08	<0.01	0.51	97.92	56.1	53.2	160	95	30	40	23	140	NA	<10	<5	
Crerar gneiss association																		
99RME-0184	4.04	0.34	0.26	<0.01	1.02	100.11	44.9	59.1	26	18	14	15	6	91	<5	<8	<8	
99RME-0189	3.33	0.29	<0.03	<0.01	0.52	99.17	45.2	58.9	28	22	13	20	12	78	<5	<8	<8	
99RME-0430	1.56	0.11	<0.03	<0.01	0.56	99.78	45.2	61.4	21	13	5	31	2	44	<5	<8	<8	
99RME-0375	1.94	0.19	0.11	0.04	0.76	99.76	31.4	55.3	30	57	41	92	26	330	9	6	14	29
Late granitoid rocks (Neoarchean?)																		
02RME-1902	4.30	0.19	0.10	0.01	0.54	99.92	32.2	59.3	20	7	8	<3	2	32	<6	<2	<1	
99RME-2139	5.52	0.03	0.20	<0.01	0.61	99.78	46.0	59.2	20	<5	<5	<5	<1	11	<5	<8	<8	
99RME-0322	2.65	0.02	0.06	<0.01	0.43	98.46	54.3	60.8	13	6	<5	<5	<1	5	14	<8	<8	14
99RME-0578	0.41	0.05	0.04	<0.01	0.44	98.33	40.0	62.8	8	<5	<5	7	<1	<5	<5	<8	<8	
99RME-0592	4.83	0.06	0.04	<0.01	0.35	98.46	40.1	58.8	19	6	<5	<5	<1	23	<5	<8	<8	
99RME-0596	3.25	0.37	0.09	0.01	0.40	98.38	34.6	60.5	22	13	12	17	5	80	<5	<8	<8	
99RME-0326	5.21	0.05	0.10	0.01	0.70	99.76	46.1	59.7	21	10	<5	<5	1	12	<5	<8	<8	
02RME-0070	14.25	<0.01	0.10	<0.01	0.23	100.79	39.8	53.2	5	<2	<12	<2	<1	<4	<6	<2	<1	
02RME-0071	14.56	<0.01	0.08	<0.01	0.21	100.77	83.2	53.3	11	<2	<12	<2	<1	<4	<6	<2	<1	
Nipissing intrusive suite (ca. 2220 Ma)																		
99RME-0023	0.24	0.02	0.05	0.05	0.27	99.51	72.1	44.8	407	192	44	145	40	208	8	13	10	31
99RME-0024	0.22	0.02	0.16	0.04	1.34	99.16	72.5	48.4	500	174	40	89	35	186	6	36	9	51
02RME-0069	2.94	0.25	0.11	0.01	0.49	100.48	28.0	54.1	26	28	35	103	21	153	17.4	<2	2.8	20
02RME-0152	1.48	0.10	0.19	0.01	0.57	100.58	53.8	53.9	91	85	49	78	26	163	42.8	<2	1.4	44
Matachewan dike swarm (ca. 2446 Ma)																		
99RME-0031	0.68	0.12	<0.03	0.12	0.68	99.36	43.0	52.6	90	81	57	278	37	319	13	38	7	58
99RME-0355	0.45	0.08	0.08	0.04	0.72	99.22	47.0	54.6	121	66	46	143	34	280	12	14	<5	26
99RME-2118	0.50	0.12	<0.03	0.03	0.80	99.75	42.8	53.3	52	66	47	143	36	315	6	8	15	29
99RME-4008	0.48	0.12	<0.03	0.08	0.71	99.36	42.7	54.4	52	64	51	157	36	318	8	16	<5	24
Matachewan	0.82	0.13	NA	NA	NA	NA	49.0	52.0	111	66	52	NA	43	344	29	NA	NA	29
Sudbury dike swarm (ca. 1238 Ma)																		
99RME-0080	1.26	0.51	<0.03	0.06	<0.05	98.72	41.5	56.9	77	89	58	57	19	236	21	<8	<5	21
99RME-0137	1.45	0.75	0.12	0.12	0.09	99.03	37.4	54.9	37	68	57	71	26	204	41	<8	<5	41
99RME-0237	1.22	0.59	<0.03	0.09	<0.05	99.64	42.1	55.7	35	86	57	54	23	190	32	<8	<5	32
99RME-0325	1.20	0.52	<0.03	0.02	<0.05	99.19	40.0	57.6	51	80	62	35	20	276	27	<8	<5	27
99RME-0337	1.25	0.59	<0.03	0.08	<0.05	99.73	41.1	57.1	45	93	61	58	20	233	25	<8	<5	25
99RME-2123	0.43	0.04	0.19	0.01	0.38	99.25	23.3	61.7	65	97	54	420	24	1229	17	18	<8	35
99RME-2178	1.36	0.70	0.16	0.10	<0.05	99.12	37.3	56.5	46	72	51	61	21	233	<5	<8	<8	
99RME-2223	0.81	0.38	0.41	0.05	<0.05	99.75	48.7	58.4	113	207	95	46	17	334	<5	<8	<8	
99RME-2256	1.18	0.56	0.20	0.07	<0.05	99.24	41.1	56.5	65	89	54	58	21	233	<5	<8	<8	
02RME-0014	0.84	0.48	0.08	0.06	<0.05	101.23	47.8	55.8	108	106	73	40	21	213	<6	<2	1.4	1
02RME-0255	1.39	0.61	0.10	0.09	0.46	100.86	39.7	57.1	103	81	83	55	24	218	16.8	<2	<1	17
Breccia body (possibly related to Sudbury dike swarm)																		
02RME-0030	2.20	0.44	0.26	0.02	0.80	100.77	39.9	59.5	69	61	51	23	18	153	<6	<2	<1	
Grenville dike swarm (ca. 590 Ma)																		
99RME-0138	0.43	0.18	<0.03	0.03	<0.05	99.85	40.9	52.0	93	97	57	383	38	359	18	19	7	44
02RME-0097	0.33	0.17	0.06	0.01	0.91	101.37	38.6	55.6	93	79	65	288	29	319	30.2	<2	1.1	31.3

NA = not analyzed. Abbreviations: CIA = chemical index of alteration, fgr = fine-grained, PGE = total Au+Pd+Pt for the sample. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 2. Listing of geochemical data on country rock units in the study area — continued.

Sample No.	Pb	Zn	Mo	W	Sn	As	Be	Rb	Cs	Ba	Sr	Ga	Li	Ta	Nb	Hf	Zr	Y	Zr/Y
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
Mafic gneiss in the Street gneiss association, Henry, Loughrin and Street townships																			
02RME-0466	16	91	NA	NA	<5	<2	0.64	23.0	0.14	210	159	18	6	0.49	6.8	2.45	117.0	26.0	5
96RME-0456	15	110	<8	<35	NA	<6	<3	33.0	0.15	410	160	NA	NA	0.75	11.0	2.30	200.0	41.0	5
96RME-0458	14	92	<8	<35	NA	<6	<3	15.0	0.06	220	180	NA	NA	0.43	7.3	1.30	120.0	28.0	4
96RME-0459	14	78	<8	<35	NA	<6	<3	14.0	0.06	220	210	NA	NA	0.38	6.5	1.20	110.0	24.0	5
Crerar gneiss association																			
99RME-0184	22	104	15	<40	NA	NA	<3	79.6	1.87	2205	1149	NA	NA	0.25	5.8	6.19	236.6	15.8	15
99RME-0189	15	84	15	<40	NA	NA	<3	124.4	1.79	938	757	NA	NA	0.67	8.0	5.25	184.4	22.3	8
99RME-0430	10	64	11	<40	NA	NA	<3	53.2	1.24	495	688	NA	NA	0.27	3.3	3.11	101.9	5.1	20
99RME-0375	17	142	<8	<40	NA	NA	4	75.0	2.22	593	157	NA	NA	1.06	12.5	4.36	166.0	47.0	4
Late granitoid rocks (Neoarchean?)																			
02RME-1902	25	47	NA	NA	<5	<2	1	91.0	0.42	1253	656	19	5	1.02	6.6	11.01	364.0	19.0	19
99RME-2139	36	15	<8	<40	NA	NA	<3	106.0	0.44	1748	950	NA	NA	0.11	1.2	2.57	92.8	0.9	108
99RME-0322	18	13	<8	<40	NA	NA	<3	32.0	0.41	2030	860	NA	NA	0.11	0.6	1.09	37.0	1.0	37
99RME-0578	3	127	15	<40	NA	NA	<3	3.6	0.12	152	1191	NA	NA	0.01	0.2	0.13	4.4	0.9	5
99RME-0592	23	35	10	<40	NA	NA	<3	124.8	0.68	1433	581	NA	NA	0.16	4.0	2.27	68.3	3.5	20
99RME-0596	17	120	10	<40	NA	NA	<3	79.4	0.27	1553	582	NA	NA	1.01	25.0	13.03	464.6	19.0	24
99RME-0326	15	22	<8	<40	NA	NA	<3	109.0	0.87	1745	673	NA	NA	0.22	2.8	3.88	143.0	5.0	29
02RME-0070	258	2	<8	<2	<5	14	0.7	990.0	7.07	137	41.0	22	<3	<0.20	0.30	<0.10	<4	0.7	
02RME-0071	285	<2	<8	<2	<5	19	0.7	892.0	10.1	171	38.6	24	<3	<0.20	1.70	<0.10	<4	1.4	
Nipissing intrusive suite (ca. 2220 Ma0.																			
99RME-0023	54	10	<8	<40	NA	NA	<3	0.4	0.40	62	68	NA	NA	0.14	1.1	0.86	31.0	11.0	3
99RME-0024	69	35	<8	<40	NA	NA	<3	0.4	0.39	66	76	NA	NA	0.12	1.1	0.78	29.0	11.0	3
02RME-0069	11	152	<8	<2	<5	2	1.3	88.8	0.74	711	195	23	NA	0.80	11.9	7.93	303.1	44.9	7
02RME-0152	14	98	<8	<2	<5	3	0.9	46.4	0.79	297	174	14	NA	0.66	9.1	4.18	159.8	32.2	5
Matachewan dike swarm (ca. 2446 Ma)																			
99RME-0031	67	72	<8	<40	NA	NA	<3	0.2	0.15	91	145	NA	NA	0.40	4.8	2.49	92.0	31.0	3
99RME-0355	110	14	<8	<40	NA	NA	<3	0.4	0.40	143	114	NA	NA	0.30	3.7	1.85	74.0	24.0	3
99RME-2118	122	5	<8	<40	NA	NA	<3	8.4	0.03	103	115	NA	NA	0.43	5.6	3.00	116.3	33.1	4
99RME-4008	129	17	<8	<40	NA	NA	<3	0.1	0.05	150	118	NA	NA	0.44	5.5	2.08	78.0	32.0	2
Matachewan	NA	NA	<8	<40	NA	NA	NA	NA	NA	206	172	NA	NA	0.42	8.8	NA	102.0	31.0	3
Sudbury dike swarm (ca. 1238 Ma)																			
99RME-0080	5	142	<8	<40	NA	NA	<3	0.6	0.56	630	430	NA	NA	0.84	13.2	4.75	204.0	34.0	6
99RME-0137	9	190	<8	<40	NA	NA	3	0.9	0.90	673	250	NA	NA	1.38	21.6	7.67	348.0	59.0	6
99RME-0237	7	170	<8	<40	NA	NA	<3	0.7	0.71	583	252	NA	NA	1.12	17.2	6.04	272.0	48.0	6
99RME-0325	6	175	<8	<40	NA	NA	3	0.6	0.62	590	295	NA	NA	1.01	15.7	5.11	226.0	39.0	6
99RME-0337	6	169	<8	<40	NA	NA	<3	0.6	0.56	700	363	NA	NA	1.03	16.1	5.39	243.0	39.0	6
99RME-2123	5	153	<8	<40	NA	NA	8	13.5	0.24	133	164	NA	NA	0.24	3.0	1.17	43.6	10.9	4
99RME-2178	7	174	<8	<40	NA	NA	<3	28.1	0.57	753	326	NA	NA	1.16	18.2	6.50	278.9	46.5	6
99RME-2223	5	206	<8	<40	NA	NA	<3	14.4	0.26	482	255	NA	NA	0.73	9.8	3.71	154.8	25.8	6
99RME-2256	6	163	<8	<40	NA	NA	<3	22.9	0.48	663	348	NA	NA	0.91	14.2	0.48	222.4	38.8	6
02RME-0014	15	138	<8	<2	<5	3	0.7	11.4	0.17	1143	528	19	NA	0.73	11.2	4.31	173.0	30.8	6
02RME-0255	9	164	<8	3	<5	<2	1.4	35.4	0.88	91	308	13	NA	1.42	20.3	7.64	317.9	46.8	6
Breccia body (possibly related to Sudbury dike swarm)																			
02RME-0030	10	139	<8	<2	<5	<2	1.6	69.6	1.81	600	220	22	NA	1.13	20.1	7.90	323.0	42.1	8
Grenville dike swarm (ca. 590 Ma)																			
99RME-0138	3	153	<8	<40	NA	NA	<3	0.6	0.63	99	90	NA	NA	0.52	7.2	3.88	148.0	43.0	3
02RME-0097	265	127	<8	<2	<5	16	0.4	6.5	0.21	170	218	24	NA	0.59	7.5	3.71	131.0	31.6	4

NA = not analyzed. Abbreviations: CIA = chemical index of alteration, fgr = fine-grained, PGE = total Au+Pd+Pt for the sample. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 2. Listing of geochemical data on country rock units in the study area — continued.

Sample No.	Th ppm	U ppm	La ppm	Ce ppm	Pr ppm	Nd ppm	Sm ppm	Eu ppm	Gd ppm	Tb ppm	Dy ppm	Ho ppm	Er ppm	Tm ppm	Yb ppm	Lu ppm	Total REE
Mafic gneiss in the Street gneiss association, Henry, Loughrin and Street townships																	
02RME-0466	7.47	1.34	22.42	42.16	5.40	20.06	4.49	1.26	4.74	0.78	4.66	1.04	2.93	0.45	2.72	0.43	113.5
96RME-0456	12.00	1.90	35.00	68.00	8.20	31.00	6.50	1.40	6.80	1.10	6.60	1.40	4.10	0.58	3.80	0.59	175.1
96RME-0458	7.10	1.20	19.00	39.00	4.70	18.00	4.00	1.00	4.30	0.70	4.30	0.89	2.60	0.36	2.50	0.38	101.7
96RME-0459	6.20	1.00	16.00	34.00	4.00	15.00	3.30	0.90	3.70	0.61	3.60	0.74	2.20	0.30	2.10	0.32	86.8
Crerar gneiss association																	
99RME-0184	10.14	1.48	91.88	145.93	23.22	82.00	11.92	3.22	6.71	0.83	4.03	0.65	1.76	0.18	1.12	0.16	373.6
99RME-0189	4.10	2.10	53.90	95.52	14.30	53.48	9.24	1.80	6.19	0.85	4.40	0.82	2.19	0.25	1.53	0.21	244.7
99RME-0430	6.23	1.78	27.20	48.82	5.89	19.08	2.55	0.60	1.41	0.17	1.02	0.17	0.49	0.05	0.39	0.05	107.9
99RME-0375	13.22	3.35	21.88	49.26	5.72	23.68	6.09	1.60	6.38	1.13	7.40	1.54	4.36	0.74	4.50	0.68	135.0
Late granitoid rocks (Neoarchean?)																	
02RME-1902	19.99	1.60	69.56	129.06	16.48	57.52	9.23	1.84	6.08	0.82	3.92	0.67	1.68	0.24	1.32	0.20	298.6
99RME-2139	12.13	0.96	4.76	10.58	0.81	2.56	0.39	0.87	0.26	0.03	0.14	0.03	0.10	0.02	0.15	0.02	20.7
99RME-0322	0.41	0.32	2.87	5.53	0.40	1.30	0.20	0.69	0.13	0.02	0.10	0.02	0.05	0.01	0.11	0.01	11.4
99RME-0578	0.31	0.06	20.37	31.31	3.34	10.02	1.06	0.56	0.47	0.03	0.27	0.01	0.08	<0.01	0.03	0.01	67.6
99RME-0592	9.04	0.48	38.81	63.24	7.04	21.43	2.42	1.32	1.23	0.13	0.79	0.12	0.38	0.03	0.28	0.03	137.3
99RME-0596	12.02	1.00	84.54	141.25	23.64	81.61	11.89	2.39	6.73	0.84	4.16	0.70	2.10	0.22	1.35	0.19	361.6
99RME-0326	7.34	1.22	18.72	47.45	3.92	14.10	2.16	0.83	1.00	0.16	0.78	0.15	0.39	0.06	0.40	0.06	90.2
02RME-0070	<0.06	0.45	0.21	0.38	0.04	0.16	0.07	0.41	0.05	0.01	0.08	0.02	0.05	0.01	0.11	0.01	1.6
02RME-0071	<0.06	0.33	0.17	0.22	0.02	0.11	0.09	0.37	0.07	0.01	0.24	0.04	0.14	0.01	0.18	0.02	1.7
Nipissing intrusive suite (ca. 2220 Ma)																	
99RME-0023	0.83	0.24	3.32	6.00	0.98	4.33	1.18	0.36	1.42	0.25	1.82	0.39	1.04	0.18	1.05	0.18	22.5
99RME-0024	0.74	0.23	3.20	5.97	0.89	3.90	1.15	0.40	1.35	0.24	1.60	0.36	1.03	0.18	1.08	0.15	21.5
02RME-0069	10.39	1.69	50.32	93.55	12.40	45.53	9.06	2.18	8.51	1.31	7.78	1.70	4.87	0.70	4.56	0.75	243.2
02RME-0152	6.75	1.44	27.30	53.79	6.55	24.02	5.18	1.39	5.29	0.92	5.63	1.22	3.46	0.56	3.34	0.54	139.2
Matachewan dike swarm (ca. 2446 Ma)																	
99RME-0031	2.04	0.52	12.94	26.12	3.65	16.16	3.91	1.14	4.36	0.73	4.87	1.03	3.01	0.51	2.88	0.46	81.8
99RME-0355	1.55	0.39	8.13	15.52	2.26	10.42	2.77	0.90	3.02	0.55	3.68	0.81	2.30	0.41	2.35	0.36	53.5
99RME-2118	2.78	0.61	13.60	26.37	3.53	15.22	3.87	1.10	4.19	0.78	5.14	1.14	3.18	0.54	3.15	0.51	82.3
99RME-4008	2.72	0.65	12.51	25.42	3.39	14.77	3.60	1.10	4.14	0.70	4.98	1.08	2.98	0.54	3.11	0.47	78.8
Matachewan	2.11	0.53	11.95	26.95	NA	NA	4.07	1.27	NA	0.83	NA	NA	NA	NA	3.25	0.50	48.8
Sudbury dike swarm (ca. 1238 Ma)																	
99RME-0080	1.98	0.55	24.00	53.77	7.01	32.03	6.96	2.25	6.61	1.00	5.95	1.19	3.11	0.51	3.09	0.44	147.9
99RME-0137	4.26	1.26	46.26	95.33	12.55	53.44	10.89	2.87	10.62	1.66	9.85	2.00	5.53	0.94	5.19	0.80	257.9
99RME-0237	3.29	0.96	30.56	62.28	8.99	40.16	9.01	2.41	8.48	1.38	7.93	1.65	4.39	0.77	4.36	0.66	183.0
99RME-0325	2.69	0.81	28.03	53.32	7.92	34.68	7.96	2.34	7.18	1.12	6.66	1.32	3.47	0.58	3.46	0.51	158.6
99RME-0337	2.47	0.70	28.25	58.27	8.36	38.25	8.18	2.48	7.57	1.14	6.63	1.34	3.66	0.62	3.60	0.52	168.9
99RME-2123	0.72	0.15	4.69	9.47	1.27	5.53	1.37	0.60	1.47	0.26	1.72	0.39	1.05	0.19	1.06	0.17	29.2
99RME-2178	2.78	0.80	32.40	71.82	9.60	43.03	9.34	2.85	8.88	1.38	7.96	1.64	4.28	0.68	4.18	0.62	198.7
99RME-2223	1.79	0.50	18.36	38.57	5.38	23.72	5.20	1.79	5.14	0.81	4.65	1.00	2.49	0.40	2.39	0.38	110.3
99RME-2256	2.16	0.59	25.82	56.82	7.78	34.29	7.57	2.46	7.22	1.13	6.65	1.38	3.53	0.59	3.27	0.51	159.0
02RME-0014	1.03	0.30	18.12	42.40	6.26	27.37	6.52	2.53	6.44	0.99	5.62	1.19	3.15	0.45	2.71	0.45	124.2
02RME-0255	3.82	1.20	34.76	73.97	10.31	42.26	9.55	2.92	9.48	1.50	8.90	1.88	5.13	0.75	4.70	0.76	206.9
Breccia body (possibly related to Sudbury dike swarm)																	
02RME-0030	5.52	1.42	33.00	71.70	9.38	37.40	8.35	2.27	7.70	1.28	7.81	1.55	4.41	0.66	4.38	0.66	190.6
Grenville dike swarm (ca. 590 Ma)																	
99RME-0138	2.44	0.68	10.66	24.27	3.70	17.26	5.00	1.35	5.71	1.02	7.04	1.47	4.08	0.70	4.00	0.59	86.9
02RME-0097	0.79	0.22	8.29	21.54	3.34	15.97	4.73	1.76	5.96	1.00	5.83	1.27	3.40	0.50	3.09	0.47	77.2

NA = not analyzed. Abbreviations: CIA = chemical index of alteration, fgr = fine-grained, PGE = total Au+Pd+Pt for the sample. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3.

Listing of Geochemical Data on East Bull Lake Intrusive Suite Rock Units in the Study Area.

Some of these data were previously published by Easton and Hrominchuk (1999, 2002) and Easton and Murphy (2002).

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area.

Sample No.	UTM 17, Easting	NAD83 Northing	Rock Type	Source	SiO_2 wt. %	TiO_2 wt. %	Al_2O_3 wt. %	Fe_2O_3* wt. %	MnO wt. %	MgO wt. %	CaO wt. %
96RME-0041	528938	5157368	opx hornblendite	1	46.20	0.27	5.29	12.66	0.14	27.04	3.89
96RME-0267	524960	5157394	opx hornblendite	1	47.25	0.31	5.40	12.38	0.13	26.83	4.13
96RME-0341	528281	5153914	opx hornblendite	1	50.49	0.32	6.01	10.99	0.19	24.17	5.55
97RME-0033	325411	5152024	opx hornblendite	1	48.28	0.42	8.27	11.69	0.21	22.48	7.81
97RME-0035	525161	5153924	ant-ep schist	2	53.05	0.36	4.71	11.86	0.23	21.43	6.13
97RME-0036	524111	5151024	fgr hornblendite	2	46.89	1.06	6.06	13.59	0.24	17.34	11.09
97RME-0037	524111	5151024	opx hornblendite	2	46.48	1.33	6.88	14.05	0.19	18.85	9.16
98RME-0049	530561	5155384	opx hornblendite	2	47.81	1.15	6.76	14.83	0.22	18.36	9.82
98RME-0055	530111	5155384	Hornblendite	2	46.89	1.06	6.06	13.59	0.24	17.34	11.09
02RME-0156	534909	5157716	opx hornblendite	3	50.28	0.33	5.75	12.56	0.22	24.73	4.79
02RME-0360	540550	5158730	opx hornblendite, altered	3	44.74	1.02	4.33	12.30	0.17	18.39	17.33
02RME-0401	546969	5158919	opx hornblendite	3	47.98	0.36	6.45	10.84	0.18	24.76	5.43
02RME-0402	547354	5158772	opx hornblendite	3	47.82	0.30	4.64	12.46	0.21	27.56	3.75
H98-103	525161	5153924	blackwall	4	46.79	0.42	8.03	13.40	0.16	18.75	6.09
H98-110	525161	5153924	cgr hornblendite	4	46.79	0.52	11.46	11.38	0.15	15.45	10.12
H98-120	525161	5153924	sheaed opx hornblendite	4	47.11	0.37	5.63	11.42	0.21	23.92	4.69
H98-200	525161	5153924	anth. schist	4	52.35	0.25	4.08	13.97	0.22	24.59	0.54
H98-202	525161	5153924	anth. schist	4	53.11	0.38	5.20	11.12	0.20	21.69	4.95
H98-300	525161	5153924	garnet amphibolite	4	50.00	0.73	14.54	16.34	0.41	6.71	7.48
H98-317	525161	5153924	black amphibolite	4	48.55	0.16	15.81	6.62	0.12	12.23	10.73
H98-401	525161	5153924	radial amphibolite	4	38.23	2.60	10.12	12.83	0.20	13.24	13.92
H98-406	525161	5153924	opx hornblendite	4	48.00	0.31	5.88	12.31	0.14	25.01	3.52
H98-408	525161	5153924	opx hornblendite	4	49.97	0.35	6.16	12.86	0.21	22.95	5.60
H98-409	525161	5153924	olivine hornblendite	4	45.96	0.40	7.95	9.81	0.13	20.82	9.10
96RME-0200	529389	5154665	black amphibolite	1	50.94	0.38	13.32	8.06	0.16	10.91	13.87
96RME-0213	530651	5155479	black amphibolite	2	48.88	0.49	19.59	10.24	0.16	5.13	10.84
96RME-0457	527416	5154634	black amphibolite	1	53.24	0.50	12.16	9.85	0.17	9.91	9.95
96RME-0460	527951	5153824	black amphibolite	1	50.95	0.37	15.91	8.03	0.14	9.10	11.23
98RME-0022	529793	5155168	anorthositic gabbro	2	49.91	1.36	16.71	14.91	0.18	3.43	8.59
98RME-0023	530066	5155339	gabbroic anorthosite	2	48.01	0.83	19.78	11.24	0.14	4.91	10.95
98RME-0024	530398	5155584	anorthositic gabbro	2	49.48	0.28	16.86	9.19	0.15	8.46	13.15
98RME-0025	530480	5155525	gabbroic anorthosite	2	48.20	0.27	23.65	6.72	0.11	4.52	12.49
98RME-0027	531148	5155624	amphibolite	2	52.26	0.49	14.77	10.25	0.18	8.93	12.07
98RME-0030	530771	5155322	leuconorite	2	51.69	0.44	14.36	9.75	0.18	9.53	12.58
98RME-0031	530560	5155354	hornblende pegmatite	2	55.35	0.16	23.09	3.01	0.05	2.31	8.02
98RME-0038	530189	5154953	border zone amphibolite	2	51.11	0.41	14.09	8.75	0.17	9.83	12.73
98RME-0047	530444	5155173	amphibolite	2	51.31	0.46	15.59	10.01	0.17	7.28	11.20
98RME-0048	530444	5155173	garnet amphibolite	2	52.12	0.56	16.83	11.26	0.14	6.27	10.93
98RME-0050	530486	5155213	gabbroic anorthosite	2	53.58	0.77	18.65	9.16	0.12	3.29	7.14
98RME-0051	534011	5155299	anorthositic gabbro	2	52.11	0.61	17.11	9.97	0.16	6.03	11.00
98RME-0052	530279	5155374	leuconorite	2	51.70	0.46	14.96	10.22	0.18	8.75	12.17
98RME-0053	530251	5155399	amphibolite	2	51.11	0.45	15.41	10.09	0.16	8.44	11.60
98RME-0062	530661	5155284	leuconorite	2	51.64	0.43	15.88	8.49	0.15	8.90	12.88
98RME-0074	529986	5155284	anorthositic gabbro	2	49.64	0.67	19.48	10.90	0.14	4.40	9.88
9C10A	554261	5169474	deformed anorthosite	5	49.30	0.26	22.80	5.62	0.12	4.15	12.20

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Sample No.	Na_2O wt. %	K_2O wt. %	P_2O_5 wt. %	CO_2 wt. %	S wt. %	LOI wt. %	Total wt. %	Mg-no.	Cr ppm	Ni ppm	Co ppm	Sc ppm	Cu ppm	V ppm
96RME-0041	0.02	0.05	0.03	0.11	0.01	2.74	98.32	80.9	>3000	870	91	17	160	110
96RME-0267	0.28	0.05	0.04	<0.10	<0.01	2.24	99.05	81.1	>3000	850	16	17	16	150
96RME-0341	0.62	0.08	<0.01	0.10	<0.01	0.27	98.69	81.3	2900	880	73	16	<5	110
97RME-0033	0.44	0.13	<0.01	0.19	<0.01	0.51	100.24	79.2	>3000	750	62	20	9	140
97RME-0035	0.60	0.05	0.02	0.25	<0.01	1.45	99.89	78.2	2170	406	72	29	6	158
97RME-0036	0.68	0.13	0.13	1.46	0.02	2.40	99.61	71.6	1384	1106	84	18	215	171
97RME-0037	0.43	0.07	0.16	1.32	0.07	2.91	100.51	72.7	839	946	88	18	159	186
98RME-0049	0.48	0.06	0.13	0.17	<0.01	0.54	100.16	71.0	1334	1008	91	19	27	183
98RME-0055	0.68	0.13	0.13	0.84	<0.01	2.40	99.61	71.6	1262	1051	76	18	5	176
02RME-0156	0.44	0.07	0.04	0.21	<0.01	0.67	99.88	79.7	3960	706	97	20	<3	104
02RME-0360	0.38	0.12	0.44	0.96	0.05	1.81	101.08	74.8	1004	343	73	49	35	184
02RME-0401	0.35	0.04	<0.01	0.20	0.01	3.33	99.73	81.9	4103	673	84	17	<3	88
02RME-0402	0.08	0.01	0.02	0.23	0.01	2.75	99.61	81.4	4395	729	90	13	4	71
H98-103	0.23	2.99	0.06	NA	NA	3.18	100.10	73.5	2720	626	103	24	2	147
H98-110	1.36	0.19	0.03	NA	NA	2.48	99.93	72.9	1377	254	87	42	56	233
H98-120	0.27	0.03	0.06	NA	NA	6.21	99.92	80.6	4029	884	118	20	16	127
H98-200	0.01	0.09	0.00	NA	NA	4.13	100.23	77.7	3801	601	121	5	1	104
H98-202	0.80	0.06	0.05	NA	NA	2.66	100.22	79.4	2492	381	94	30	1	147
H98-300	1.52	0.40	0.31	NA	NA	1.69	100.13	44.9	59	1	109	44	100	311
H98-317	1.65	0.23	0.02	NA	NA	3.74	99.86	78.5	845	158	57	27	1	89
H98-401	3.12	1.40	1.05	NA	NA	0.00	96.71	67.1	345	262	58	21	79	236
H98-406	0.41	0.08	0.04	NA	NA	4.19	99.89	80.1	4723	1019	106	22	79	127
H98-408	0.35	0.13	0.05	NA	NA	1.61	100.24	77.9	3330	862	98	22	40	131
H98-409	0.40	0.16	0.03	NA	NA	5.06	99.82	80.8	3027	752	90	26	1	152
96RME-0200	1.10	0.45	0.04	<0.10	0.02	0.69	99.92	72.8	1134	170	36	40	68	200
96RME-0213	2.92	0.68	0.08	<0.10	<0.01	0.61	99.62	49.8	48	73	40	26	31	160
96RME-0457	1.61	0.85	0.01	0.10	<0.01	0.65	98.90	66.6	830	190	50	28	54	150
96RME-0460	1.60	0.75	<0.01	0.09	<0.01	0.69	98.77	69.2	760	140	40	24	52	140
98RME-0022	3.66	1.26	0.17	0.12	<0.01	0.50	100.68	31.3	8	40	46	33	185	351
98RME-0023	2.94	0.80	0.04	0.09	<0.01	0.56	100.20	46.4	30	78	44	31	158	538
98RME-0024	1.97	0.24	0.03	0.11	<0.01	0.58	100.39	64.6	578	162	49	40	6	164
98RME-0025	3.01	0.32	0.03	0.11	<0.01	0.57	99.89	57.1	111	64	26	21	105	116
98RME-0027	1.62	0.31	0.04	0.10	0.05	0.63	101.55	63.3	115	139	47	43	172	241
98RME-0030	1.41	0.27	0.03	0.11	0.03	0.18	100.42	65.9	167	165	50	45	171	241
98RME-0031	5.00	1.14	0.01	0.20	<0.01	1.06	99.20	60.3	25	36	11	11	9	64
98RME-0038	1.41	0.40	0.03	0.45	0.04	0.93	99.86	69.0	473	187	43	41	157	220
98RME-0047	1.99	0.45	0.04	0.64	0.05	1.62	100.12	59.0	75	109	45	37	114	217
98RME-0048	2.03	0.52	0.05	0.14	<0.01	0.70	101.41	52.4	43	88	44	35	36	236
98RME-0050	4.27	1.73	0.09	0.32	<0.01	1.08	99.88	41.6	11	36	33	25	64	221
98RME-0051	1.87	0.55	0.06	0.14	0.04	0.85	100.32	54.5	31	83	41	35	165	241
98RME-0052	1.56	0.29	0.04	0.14	0.04	0.26	100.59	62.9	102	141	52	43	172	243
98RME-0053	1.98	0.36	0.04	0.18	0.01	1.04	100.68	62.4	99	132	49	41	102	232
98RME-0062	1.50	0.25	0.04	0.14	0.03	0.39	100.55	67.5	563	171	43	38	82	211
98RME-0074	3.19	0.87	0.05	0.24	<0.01	0.96	100.18	44.4	16	60	45	29	115	399
9C10A	2.68	0.86	0.06	0.06	0.01	1.63	99.68	59.4	NA	NA	NA	NA	NA	NA

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Sample No.	Au ppb	Pd ppb	Pt ppb	PGE ppb	Pb ppm	Zn ppm	Mo ppm	W ppm	Sn ppm	As ppm	Rb ppm	Cs ppm	Ba ppm	Sr ppm
96RME-0041	NA	NA	NA		<7	88	13	NA	NA	NA	4	NA	24	14
96RME-0267	NA	NA	NA		<7	81	12	NA	NA	NA	3	NA	20	20
96RME-0341	NA	NA	NA		<7	52	<8	NA	NA	NA	1	0.03	33	5
97RME-0033	NA	NA	NA		<7	57	13	NA	NA	NA	1	<0.1	10	20
97RME-0035	NA	NA	NA		<7	106	<8	NA	NA	NA	1	0.03	36	23
97RME-0036	NA	NA	NA		8	172	<8	NA	NA	NA	1	0.10	17	50
97RME-0037	NA	NA	NA		<7	142	<8	NA	NA	NA	1	0.10	<8	14
98RME-0049	NA	NA	NA		<7	143	<8	NA	NA	NA	1	0.05	26	13
98RME-0055	NA	NA	NA		<7	127	<8	NA	NA	NA	6	0.10	46	34
02RME-0156	9.4	<2	3.6	13	13	102	<8	<2	9	<2	1	0.10	650	12
02RME-0360	<6	<2	<1	<9	10	99	NA	NA	<5	<2	3	0.12	137	503
02RME-0401	<6	<2	1.3	1	7	76	NA	NA	<5	<2	0	0.05	<25	42
02RME-0402	<6	<2	3.6	4	6	87	NA	NA	<5	<2	0	0.09	<25	81
H98-103	NA	NA	NA		<7	77	<8	NA	NA	NA	154	NA	885	17
H98-110	NA	NA	NA		<7	57	<8	NA	NA	NA	2	NA	19	51
H98-120	NA	NA	NA		<7	48	<8	NA	NA	NA	NA	NA	2	12
H98-200	NA	NA	NA		<7	78	<8	NA	NA	NA	2	NA	35	9
H98-202	NA	NA	NA		<7	68	<8	NA	NA	NA	1	NA	35	24
H98-300	NA	NA	NA		<7	1	<8	NA	NA	NA	1	NA	190	80
H98-317	NA	NA	NA		<7	53	<8	NA	NA	NA	1	NA	6	179
H98-401	NA	NA	NA		<7	113	<8	NA	NA	NA	43	NA	999	1374
H98-406	NA	NA	NA		<7	53	<8	NA	NA	NA	2	NA	1	16
H98-408	NA	NA	NA		<7	55	<8	NA	NA	NA	NA	NA	1	11
H98-409	NA	NA	NA		<7	65	<8	NA	NA	NA	NA	NA	1	21
96RME-0200	NA	NA	NA		<7	56	<8	NA	NA	NA	8	NA	94	98
96RME-0213	NA	NA	NA		9	74	<8	NA	NA	NA	13	NA	193	272
96RME-0457	NA	NA	NA		9	79	<8	NA	NA	NA	17	0.09	180	140
96RME-0460	NA	NA	NA		7	65	<8	NA	NA	NA	24	NA	190	170
98RME-0022	NA	NA	NA		9	149	<8	NA	NA	NA	23	0.16	333	248
98RME-0023	NA	NA	NA		<7	82	<8	NA	NA	NA	21	0.51	200	302
98RME-0024	NA	NA	NA		8	72	<8	NA	NA	NA	3	0.03	73	234
98RME-0025	NA	NA	NA		<7	59	<8	NA	NA	NA	3	0.01	115	354
98RME-0027	NA	NA	NA		11	90	<8	NA	NA	NA	11	0.37	100	121
98RME-0030	NA	NA	NA		<7	84	<8	NA	NA	NA	9	0.42	131	117
98RME-0031	NA	NA	NA		22	44	10	NA	NA	NA	43	3.08	407	625
98RME-0038	NA	NA	NA		8	80	<8	NA	NA	NA	11	0.25	112	113
98RME-0047	NA	NA	NA		<7	91	<8	NA	NA	NA	14	0.39	125	157
98RME-0048	NA	NA	NA		8	110	<8	NA	NA	NA	15	0.14	150	167
98RME-0050	NA	NA	NA		10	103	<8	NA	NA	NA	69	0.81	456	314
98RME-0051	NA	NA	NA		<7	91	<8	NA	NA	NA	13	0.12	132	174
98RME-0052	NA	NA	NA		<7	93	<8	NA	NA	NA	9	0.38	115	126
98RME-0053	NA	NA	NA		<7	97	<8	NA	NA	NA	11	0.18	96	120
98RME-0062	NA	NA	NA		<7	81	<8	NA	NA	NA	9	0.42	93	116
98RME-0074	NA	NA	NA		12	96	<8	NA	NA	NA	19	0.20	205	303
9C10A	NA	NA	NA		NA	NA	<8	NA	NA	NA	NA	0.05	NA	NA

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Sample No.	Be ppm	Ga ppm	Li ppm	Ta ppm	Nb ppm	Hf ppm	Zr ppm	Y ppm	Zr/Y	Th ppm	U ppm
96RME-0041	<3	NA	NA	NA	3.0	NA	37	14	2.6	<10.0	NA
96RME-0267	<3	NA	NA	NA	3.0	NA	42	10	4.2	<3.0	NA
96RME-0341	<3	NA	NA	0.24	2.6	0.80	41	12	3.4	1.7	0.4
97RME-0033	<3	NA	NA	0.31	3.6	NA	59	11	5.4	2.1	0.6
97RME-0035	<3	NA	NA	NA	0.8	NA	51	11	4.6	1.4	0.4
97RME-0036	<3	NA	NA	NA	12.8	NA	106	16	6.6	3.6	0.9
97RME-0037	<3	NA	NA	NA	15.9	NA	123	20	6.2	3.5	0.9
98RME-0049	<3	NA	NA	NA	14.0	NA	116	19	6.1	3.8	0.9
98RME-0055	<3	NA	NA	NA	9.3	NA	87	14	6.2	1.0	0.3
02RME-0156	0.2	26	<2	0.24	2.2	1.14	42	9	4.7	1.7	0.5
02RME-0360	0.2	10	<2	<0.17	1.0	1.46	54	21	2.6	0.1	0.1
02RME-0401	0.2	7	<2	<0.17	2.4	1.17	37	12	3.1	0.5	0.3
02RME-0402	0.1	5	<2	0.18	2.2	0.99	35	8	4.4	0.9	0.2
H98-103	NA	NA	NA	NA	1.1	NA	57	20	2.9	NA	NA
H98-110	NA	NA	NA	NA	0.8	NA	74	25	3.0	NA	NA
H98-120	NA	NA	NA	NA	0.5	NA	44	5	8.8	NA	NA
H98-200	NA	NA	NA	NA	3.6	NA	23	6	3.8	NA	NA
H98-202	NA	NA	NA	NA	5.2	NA	63	14	4.5	NA	NA
H98-300	NA	NA	NA	NA	0.3	NA	100	46	2.2	NA	NA
H98-317	NA	NA	NA	NA	1.4	NA	22	6	3.7	NA	NA
H98-401	NA	NA	NA	NA	105.0	NA	267	32	8.3	NA	NA
H98-406	NA	NA	NA	NA	1.5	NA	43	8	5.4	NA	NA
H98-408	NA	NA	NA	NA	0.9	NA	56	13	4.3	NA	NA
H98-409	NA	NA	NA	NA	1.0	NA	51	19	2.7	NA	NA
96RME-0200	<3	NA	NA	NA	3.0	NA	32	13	2.5	<10.0	NA
96RME-0213	<3	NA	NA	NA	3.0	NA	62	17	3.6	<10.0	NA
96RME-0457	<3	NA	NA	0.38	5.8	1.20	96	22	4.4	5.6	0.9
96RME-0460	<3	NA	NA	0.21	3.0	1.40	62	16	3.9	2.4	0.6
98RME-0022	3.0	NA	NA	NA	6.0	NA	123	30	4.1	4.0	0.8
98RME-0023	4.0	NA	NA	NA	1.1	NA	34	9	3.8	0.6	0.1
98RME-0024	<3	NA	NA	NA	0.8	NA	29	9	3.2	0.6	0.1
98RME-0025	<3	NA	NA	NA	0.8	NA	28	7	4.0	0.6	0.1
98RME-0027	<3	NA	NA	NA	1.6	NA	40	13	3.1	1.1	0.3
98RME-0030	<3	NA	NA	NA	1.4	NA	39	12	3.3	1.0	0.3
98RME-0031	<3	NA	NA	NA	1.2	NA	21	6	3.5	1.3	0.6
98RME-0038	<3	NA	NA	NA	1.4	NA	35	11	3.2	1.0	0.3
98RME-0047	<3	NA	NA	NA	1.7	NA	42	13	3.2	1.2	0.4
98RME-0048	<3	NA	NA	NA	1.8	NA	49	15	3.3	1.6	0.4
98RME-0050	<3	NA	NA	NA	4.4	NA	92	16	5.8	5.2	0.6
98RME-0051	<3	NA	NA	NA	2.3	NA	56	16	3.5	1.8	0.5
98RME-0052	<3	NA	NA	NA	1.4	NA	40	12	3.3	1.0	0.3
98RME-0053	<3	NA	NA	NA	1.5	NA	38	12	3.2	1.1	0.3
98RME-0062	<3	NA	NA	NA	0.7	NA	38	11	3.5	0.9	0.2
98RME-0074	3.0	NA	NA	NA	1.4	NA	50	11	4.5	0.8	0.2
9C10A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Sample No.	La ppm	Ce ppm	Pr ppm	Nd ppm	Sm ppm	Eu ppm	Gd ppm	Tb ppm	Dy ppm	Ho ppm	Er ppm	Tm ppm	Yb ppm	Lu ppm	Total REE
96RME-0041	4.90	11.04	1.44	5.77	1.35	0.21	1.47	0.25	1.53	0.34	1.03	0.15	0.97	0.15	30.6
96RME-0267	4.55	10.50	1.34	5.52	1.25	0.24	1.39	0.23	1.50	0.32	0.96	0.14	0.89	0.15	29.0
96RME-0341	4.80	11.00	1.40	6.00	1.30	0.35	1.50	0.23	1.40	0.30	0.90	0.13	0.94	0.15	30.4
97RME-0033	9.17	19.22	2.32	9.46	2.00	0.58	1.98	0.33	2.18	0.45	1.38	0.21	1.24	0.20	50.7
97RME-0035	5.81	13.41	1.74	7.14	1.55	0.47	1.57	0.26	1.76	0.36	1.16	0.16	1.13	0.17	36.7
97RME-0036	18.98	42.74	5.27	21.70	4.38	1.06	3.58	0.52	3.19	0.58	1.66	0.22	1.42	0.21	105.5
97RME-0037	15.44	36.33	4.94	21.31	4.59	1.31	4.00	0.60	3.71	0.69	2.04	0.28	1.76	0.26	97.3
98RME-0049	16.75	41.13	5.21	22.05	4.65	1.20	3.96	0.56	3.43	0.62	1.88	0.24	1.58	0.23	103.5
98RME-0055	13.67	35.07	4.74	19.81	4.03	1.20	3.41	0.49	2.93	0.53	1.52	0.20	1.24	0.19	89.0
02RME-0156	6.04	12.44	1.48	5.56	1.35	0.41	1.42	0.25	1.57	0.34	0.93	0.17	0.97	0.17	33.1
02RME-0360	5.50	29.41	7.37	44.87	12.68	3.01	10.06	1.17	4.90	0.85	1.65	0.22	1.19	0.16	123.0
02RME-0401	5.07	10.54	1.31	5.21	1.18	0.47	1.27	0.24	1.50	0.34	0.92	0.15	0.99	0.17	29.4
02RME-0402	4.66	8.79	1.03	4.06	0.84	0.28	0.92	0.16	0.91	0.21	0.62	0.10	0.64	0.11	23.3
H98-103	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
H98-110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
H98-120	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
H98-200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
H98-202	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
H98-300	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
H98-317	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
H98-401	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
H98-406	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
H98-408	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
H98-409	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
96RME-0200	2.35	5.62	0.80	3.62	1.07	0.36	1.38	0.24	1.65	0.36	1.05	0.16	1.01	0.16	19.8
96RME-0213	8.69	19.47	2.52	10.26	2.35	0.93	2.48	0.41	2.52	0.56	1.65	0.25	1.57	0.24	53.9
96RME-0457	17.00	33.00	3.90	15.00	3.20	0.78	3.40	0.56	3.40	0.72	2.10	0.29	2.00	0.31	85.7
96RME-0460	9.40	19.00	2.30	9.00	2.00	0.64	2.30	0.35	2.20	0.45	1.40	0.19	1.30	0.21	50.7
98RME-0022	19.79	40.88	5.11	20.98	4.58	1.33	4.64	0.72	4.80	1.01	2.95	0.42	2.80	0.43	110.4
98RME-0023	3.79	7.98	1.03	4.56	1.11	0.51	1.21	0.21	1.38	0.28	0.88	0.12	0.85	0.13	24.0
98RME-0024	3.28	6.82	0.90	4.01	1.00	0.42	1.16	0.21	1.43	0.29	0.90	0.13	0.91	0.14	21.6
98RME-0025	3.49	7.17	0.92	4.00	0.95	0.37	1.04	0.16	1.16	0.24	0.75	0.11	0.73	0.11	21.2
98RME-0027	4.19	8.77	1.19	5.37	1.44	0.48	1.72	0.30	1.97	0.43	1.31	0.18	1.30	0.20	28.9
98RME-0030	3.90	8.26	1.09	4.87	1.29	0.43	1.58	0.27	1.90	0.40	1.22	0.17	1.20	0.18	26.8
98RME-0031	1.59	4.62	0.63	2.84	0.82	0.42	0.90	0.15	0.95	0.21	0.57	0.08	0.53	0.07	14.4
98RME-0038	3.85	7.85	1.04	4.66	1.25	0.42	1.48	0.26	1.76	0.38	1.13	0.16	1.13	0.17	25.5
98RME-0047	4.67	9.84	1.27	5.54	1.47	0.53	1.76	0.30	2.00	0.43	1.29	0.18	1.24	0.19	30.7
98RME-0048	6.27	12.93	1.62	6.84	1.79	0.60	2.13	0.35	2.38	0.50	1.49	0.22	1.48	0.23	38.8
98RME-0050	17.96	36.95	4.44	17.28	3.27	0.80	2.78	0.41	2.69	0.53	1.57	0.21	1.38	0.22	90.5
98RME-0051	6.85	14.05	1.77	7.74	1.92	0.62	2.33	0.39	2.54	0.53	1.60	0.24	1.62	0.26	42.5
98RME-0052	4.01	8.55	1.12	5.01	1.32	0.47	1.58	0.28	1.88	0.42	1.24	0.18	1.20	0.18	27.4
98RME-0053	4.53	8.92	1.14	4.92	1.34	0.48	1.59	0.28	1.88	0.40	1.19	0.17	1.22	0.17	28.2
98RME-0062	3.75	7.96	1.05	4.61	1.29	0.44	1.53	0.26	1.90	0.40	1.17	0.17	1.14	0.18	25.8
98RME-0074	5.30	11.14	1.42	6.09	1.46	0.58	1.58	0.26	1.81	0.39	1.14	0.16	1.10	0.18	32.6
9C10A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Sample No.	UTM 17, Easting	NAD83 Northing	Rock Type	Source	SiO_2 wt. %	TiO_2 wt. %	Al_2O_3 wt. %	$Fe_2O_3^*$ wt. %	MnO wt. %	MgO wt. %	CaO wt. %
98RME-0350	555261	5172689	gabbro, Dana North	6	48.94	0.71	15.44	12.64	0.19	7.54	11.01
98RME-0351	555261	5172689	gabbro, Dana North	6	49.80	0.19	15.44	11.57	0.20	9.54	8.80
98RME-0354	559171	5167624	anorthositic norite, Azen	6	49.80	0.20	22.31	6.66	0.10	5.80	12.42
99RME-0098	554531	5169099	deformed, dendritic gabbro	6	51.00	1.54	14.30	17.01	0.21	3.71	8.15
99RME-0269	556561	5172664	gabbro	6	50.90	0.45	16.11	10.79	0.18	7.23	10.80
99RME-0273	556491	5173714	feldspar-phyric gabbro	6	47.33	0.79	15.56	12.30	0.19	7.87	10.01
99RME-0386	557381	5160074	anorthosite	6	47.68	0.13	30.29	2.32	0.03	1.22	14.64
99RME-0388	557171	5160204	norite	6	49.94	0.18	21.38	5.31	0.09	5.72	12.61
99RME-0399	556286	5160299	melanorite	6	41.42	0.21	10.67	16.58	0.20	20.85	5.78
99RME-0454	557766	5160899	norite	6	51.16	0.23	17.02	7.72	0.14	9.54	12.58
99RME-0459	557541	5161139	melanorite	6	42.11	0.15	11.86	17.01	0.22	18.98	6.63
99RME-0463	556886	5161009	leucogabbro	6	48.94	0.61	22.13	8.79	0.08	3.29	12.80
99RME-0505	556741	5160764	gabbro+magnetite	7	46.11	1.24	20.78	13.49	0.12	3.57	11.42
99RME-0516	557424	5160224	ultramafic	7	43.13	0.93	6.09	13.75	0.18	21.62	8.07
99RME-0543	557576	5159763	anorthositic gabbro	7	50.54	0.14	17.89	6.77	0.13	9.12	12.47
99RME-0545	557576	5159763	gabbro	7	49.42	0.47	2.50	25.12	0.40	18.95	2.84
99RME-0763	554501	5164514	amphibolite	7	49.62	1.00	13.97	15.23	0.23	5.80	9.95
99RME-0786	556801	5160084	norite	7	49.55	0.21	20.47	5.94	0.10	6.42	13.11
99RME-0787	556016	5160864	anorthosite	7	48.86	0.16	28.97	2.77	0.04	1.08	13.99
99RME-2002	560506	5166027	noritic anorthosite	6	47.33	0.07	27.14	5.09	0.06	4.46	13.02
99RME-2013	560948	5165965	noritic anorthosite	6	48.39	0.12	27.45	4.10	0.06	2.92	13.21
99RME-2021	560921	5166379	noritic anorthosite	6	50.17	0.14	25.58	4.86	0.08	3.61	12.71
99RME-2026	560247	5165420	altered noritic anorthosite	6	49.53	0.17	26.09	3.94	0.06	3.46	12.43
99RME-2050	560723	5166993	anorthositic norite	6	47.55	0.10	21.78	8.52	0.11	8.52	10.95
99RME-2064	560496	5167369	gabbronorite	6	50.76	0.20	15.63	8.36	0.15	10.68	12.47
99RME-2100	558029	5168905	gabbroic anorthosite	6	50.15	0.30	23.66	5.30	0.08	3.98	13.48
99RME-2116	556346	5166811	gabbronoritic anorthosite	6	49.59	0.16	25.52	4.12	0.07	3.17	13.65
99RME-2147	558947	5166224	gabbro	6	50.76	0.18	19.55	6.51	0.12	6.03	13.90
99RME-2165	557094	5167523	norite	6	48.40	0.18	16.65	11.37	0.17	10.75	11.19
99RME-2170	558951	5167673	norite	6	49.41	0.29	21.77	7.54	0.11	5.37	11.89
99RME-2190	558229	5166031	norite	6	48.63	0.14	18.64	9.93	0.15	8.88	11.58
99RME-2193	557983	5166158	norite with magnetite	6	46.70	0.10	19.47	9.35	0.12	11.79	10.08
99RME-2198	559325	5166635	norite with magnetite	6	47.05	0.35	25.53	6.95	0.08	5.12	12.55
99RME-2203	558906	5166311	gabbronorite	6	50.54	0.18	21.66	6.99	0.12	4.98	11.48
99RME-2213	558352	5164835	anorthositic norite	6	51.28	0.19	23.23	6.13	0.10	4.59	11.79
99RME-2224	558522	5165429	anorthositic norite	6	48.58	0.54	24.19	8.25	0.11	3.14	12.92
99RME-2230	560688	5164809	gabbroic anorthosite	6	49.39	0.24	26.65	4.49	0.06	2.43	13.95
99RME-2240	559171	5167680	leuconorite, Azen zone	8	50.08	0.25	23.52	6.49	0.10	4.90	11.79
99RME-2242	559150	5167678	troctolite inclusion, Azen	8	44.14	0.16	12.79	17.25	0.20	15.67	7.18
99RME-2243	559149	5167677	olivine gabbronorite, Azen	8	48.42	0.21	18.81	10.82	0.14	10.16	9.82
99RME-2244	558522	5165429	gabbronoritic anorthosite	6	51.07	0.10	22.84	6.05	0.11	5.38	10.91
99RME-2249	560107	5165385	gabbroic anorthosite	6	49.30	0.17	23.29	5.77	0.09	4.64	12.80
99RME-2257	560135	5164654	gabbroic anorthosite	6	48.55	0.46	24.09	7.10	0.10	3.16	12.90
99RME-2291	558431	5168104	fine-grained norite	7	51.16	0.33	13.10	8.27	0.15	11.48	13.12
99RME-2330	563210	5165448	gabbro	7	50.94	0.11	22.02	5.29	0.10	5.73	12.62

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Sample No.	Na_2O wt. %	K_2O wt. %	P_2O_5 wt. %	CO_2 wt. %	S wt. %	LOI wt. %	Total wt. %	Mg-no.	Cr ppm	Ni ppm	Co ppm	Sc ppm	Cu ppm	V ppm
98RME-0350	1.73	0.82	0.02	<0.03	0.08	1.06	100.10	54.2	102	145	38	34	502	257
98RME-0351	1.99	0.62	0.01	<0.03	0.11	2.28	100.44	62.0	229	276	59	28	631	119
98RME-0354	2.16	0.32	0.02	<0.03	0.02	0.38	100.17	63.3	231	150	30	16	114	95
99RME-0098	2.88	0.99	0.17	0.06	0.03	0.95	100.91	30.2	17	NA	NA	NA	NA	NA
99RME-0269	2.70	0.44	0.02	<0.03	0.05	1.10	100.72	57.0	255	148	50	29	117	247
99RME-0273	2.03	0.84	0.06	1.17	0.03	3.81	100.79	55.9	75	95	45	39	142	223
99RME-0386	2.23	0.23	0.02	0.06	<0.01	0.63	99.42	51.0	61	24	6	2	23	40
99RME-0388	2.44	0.36	0.01	0.04	0.01	0.60	98.64	68.1	>500	93	26	18	29	109
99RME-0399	0.78	0.14	0.01	0.74	0.02	3.27	99.91	71.4	109	714	133	11	42	85
99RME-0454	1.79	0.19	0.02	<0.03	<0.01	0.44	100.83	71.0	439	139	41	30	26	143
99RME-0459	1.24	0.11	0.01	0.18	0.01	1.63	99.95	68.8	90	629	128	12	40	75
99RME-0463	3.13	0.25	0.01	<0.03	<0.01	0.33	100.36	42.6	12	38	30	30	15	246
99RME-0505	2.82	0.22	0.01	0.11	<0.01	0.21	99.99	34.4	11	54	50	24	101	437
99RME-0516	0.24	0.04	0.14	1.65	0.02	5.14	99.33	75.7	>500	1221	98	9	84	146
99RME-0543	1.86	0.24	0.01	0.03	<0.01	0.82	99.99	72.7	440	150	39	14	20	102
99RME-0545	0.30	0.07	0.01	0.07	0.02	0.70	100.78	59.9	346	215	90	43	108	263
99RME-0763	1.81	0.71	0.16	0.06	0.01	0.65	99.13	43.0	126	68	57	32	98	369
99RME-0786	2.11	0.26	0.01	0.07	<0.01	0.62	98.80	68.1	404	109	32	16	34	120
99RME-0787	2.83	0.18	0.02	0.06	<0.01	0.59	99.49	43.5	31	15	9	2	30	58
99RME-2002	2.24	0.12	0.01	<0.03	<0.01	0.51	100.05	63.4	40	138	29	4	21	33
99RME-2013	2.70	0.35	0.01	<0.03	<0.01	0.62	99.93	58.5	39	52	17	4	21	43
99RME-2021	2.56	0.25	0.01	0.04	<0.01	0.40	100.37	59.5	69	48	18	9	23	57
99RME-2026	2.94	0.37	0.01	0.06	<0.01	0.91	99.91	63.5	<1	41	17	12	16	87
99RME-2050	2.18	0.24	0.01	0.21	0.02	0.71	100.67	66.4	87	257	52	10	65	60
99RME-2064	1.51	0.17	0.01	0.10	<0.01	0.75	100.69	71.7	>500	185	46	31	36	155
99RME-2100	2.69	0.25	0.02	0.04	<0.01	0.47	100.38	59.8	245	71	19	18	84	123
99RME-2116	2.41	0.30	0.01	0.03	<0.01	0.98	99.98	60.4	138	44	13	13	46	75
99RME-2147	2.40	0.35	0.01	0.04	<0.01	0.64	100.45	64.7	219	109	36	39	49	162
99RME-2165	1.67	0.14	0.01	0.05	<0.01	0.58	101.11	65.2	306	322	70	23	68	106
99RME-2170	2.32	0.40	0.04	0.09	0.01	0.42	99.56	58.5	156	139	32	17	52	116
99RME-2190	1.78	0.18	0.01	0.03	<0.01	0.67	100.59	63.9	223	181	54	21	62	89
99RME-2193	1.79	0.19	0.01	0.33	<0.01	0.94	100.54	71.4	136	385	66	9	21	56
99RME-2198	2.02	0.24	0.02	0.06	0.02	0.43	100.34	59.3	30	196	33	7	51	106
99RME-2203	2.74	0.36	0.01	0.28	<0.01	0.99	100.05	58.5	50	66	29	18	45	97
99RME-2213	2.82	0.28	0.02	0.13	<0.01	0.52	100.95	59.7	112	60	23	14	72	72
99RME-2224	2.62	0.15	0.07	0.08	0.01	0.32	100.89	43.0	101	39	24	18	116	175
99RME-2230	2.61	0.24	0.03	<0.03	<0.01	0.38	100.47	51.7	160	32	14	11	47	88
99RME-2240	2.47	0.43	0.02	<0.03	0.02	0.33	100.38	59.9	16	135	28	13	119	98
99RME-2242	1.18	0.20	0.01	<0.03	0.67	<0.05	98.78	64.3	203	1840	119	15	4512	93
99RME-2243	1.87	0.30	0.03	0.07	0.18	0.25	100.83	65.0	250	623	65	14	1320	91
99RME-2244	3.03	0.22	0.01	0.08	<0.01	0.72	100.44	63.8	86	83	28	11	18	55
99RME-2249	2.81	0.37	0.01	0.13	<0.01	0.74	99.99	61.4	181	75	26	17	40	90
99RME-2257	2.54	0.30	0.05	0.05	<0.01	0.40	99.65	46.8	35	41	22	19	78	160
99RME-2291	0.58	0.15	0.04	0.27	<0.01	1.29	99.67	73.3	>500	211	31	38	211	180
99RME-2330	2.53	0.13	0.01	0.11	<0.01	0.81	100.29	68.2	89	87	27	15	31	85

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Sample No.	Au ppb	Pd ppb	Pt ppb	PGE ppb	Pb ppm	Zn ppm	Mo ppm	W ppm	Sn ppm	As ppm	Rb ppm	Cs ppm	Ba ppm	Sr ppm
98RME-0350	22	427	162	611	5	0	<8	NA	NA	NA	30	1.32	456	624
98RME-0351	24	476	179	679	4	123	<8	NA	NA	NA	18	0.43	249	240
98RME-0354	9	9	19	37	2	114	<8	NA	NA	NA	6	0.20	126	275
99RME-0098	<5	8	12	20	6	162	<8	NA	NA	NA	26	0.54	274	153
99RME-0269	<5	15	13	28	9	111	<8	NA	NA	NA	34	0.79	141	190
99RME-0273	<5	133	62	195	4	104	<8	NA	NA	NA	17	0.62	109	285
99RME-0386	<5	<8	<8	<21	2	23	2	NA	NA	NA	2	0.09	74	324
99RME-0388	<5	<8	<8	<21	1	47	2	NA	NA	NA	4	0.28	104	289
99RME-0399	<5	12	<8	12	1	114	<8	NA	NA	NA	3	0.34	56	94
99RME-0454	<5	<8	<8	0	1	59	<8	NA	NA	NA	3	0.15	92	170
99RME-0459	<5	8	10	18	1	118	<8	NA	NA	NA	1	0.05	51	112
99RME-0463	<5	21	<8	21	1	52	<8	NA	NA	NA	2	0.13	87	285
99RME-0505	8	27	29	64	1	106	<1	NA	NA	NA	2	0.20	108	323
99RME-0516	<5	<8	<8	<21	1	131	<1	NA	NA	NA	0	0.03	<5	46
99RME-0543	<5	<8	<8	<21	3	65	<1	NA	NA	NA	1	0.06	87	156
99RME-0545	11	24	124	159	1	175	<1	NA	NA	NA	2	0.26	6	6
99RME-0763	<5	15	15	30	6	150	1	NA	NA	NA	11	0.02	332	106
99RME-0786	<5	<8	<8	<21	1	50	1	NA	NA	NA	1	0.05	100	191
99RME-0787	<5	<8	<8	<21	3	31	<1	NA	NA	NA	2	0.08	59	232
99RME-2002	<5	85	10	95	1	40	<8	NA	NA	NA	2	0.04	80	276
99RME-2013	<5	9	18	27	1	39	<8	NA	NA	NA	4	0.10	89	258
99RME-2021	<5	<8	13	13	2	47	<8	NA	NA	NA	4	0.11	126	268
99RME-2026	<5	<8	14	14	151	42	<8	NA	NA	NA	0	0.30	65	1
99RME-2050	<5	<8	<8	<21	1	65	<8	NA	NA	NA	3	0.10	98	232
99RME-2064	<5	<8	<8	<21	1	66	<8	NA	NA	NA	3	0.07	70	159
99RME-2100	<5	11	9	20	2	47	<8	NA	NA	NA	5	0.12	122	437
99RME-2116	5	19	15	39	2	36	<8	NA	NA	NA	4	0.23	85	298
99RME-2147	<5	<8	9	9	1	64	<8	NA	NA	NA	7	0.24	100	253
99RME-2165	<5	16	20	36	2	81	<8	NA	NA	NA	2	0.14	65	180
99RME-2170	<5	11	11	22	2	67	<8	NA	NA	NA	8	0.33	143	281
99RME-2190	7	37	34	78	1	72	<8	NA	NA	NA	3	0.14	81	212
99RME-2193	<5	<8	<8	<21	2	71	<8	NA	NA	NA	2	0.09	72	252
99RME-2198	<5	9	8	17	1	56	<8	NA	NA	NA	4	0.13	85	294
99RME-2203	<5	19	16	35	2	59	<8	NA	NA	NA	5	0.22	118	292
99RME-2213	<5	70	50	120	2	53	<8	NA	NA	NA	4	0.12	107	279
99RME-2224	<5	<8	13	13	2	73	<8	NA	NA	NA	3	0.10	101	263
99RME-2230	<5	<8	<8	<21	2	41	<8	NA	NA	NA	4	0.09	101	276
99RME-2240	<5	<8	<8	<21	2	57	<8	NA	NA	NA	7	0.27	145	425
99RME-2242	145	1980	576	2701	6	122	<8	NA	NA	NA	3	0.25	81	164
99RME-2243	59	293	106	458	3	84	<8	NA	NA	NA	5	0.42	110	255
99RME-2244	<5	<8	<8	<21	1	51	<8	NA	NA	NA	3	0.17	89	303
99RME-2249	<5	16	11	27	1	47	<8	NA	NA	NA	6	0.54	95	266
99RME-2257	<5	10	14	24	2	64	<8	NA	NA	NA	6	0.23	115	265
99RME-2291	10	12	19	41	NA	68	<8	NA	NA	NA	5	NA	54	92
99RME-2330	<5	<8	<8	<21	1	45	<1	NA	NA	NA	2	0.03	79	286

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Sample No.	Be ppm	Ga ppm	Li ppm	Ta ppm	Nb ppm	Hf ppm	Zr ppm	Y ppm	Zr/Y	Th ppm	U ppm
98RME-0350	<3	NA	NA	0.08	0.5	0.51	14	13	1.1	0.2	0.1
98RME-0351	<3	NA	NA	0.08	0.4	0.32	11	6	1.8	0.2	0.1
98RME-0354	<3	NA	NA	0.08	0.6	0.56	20	7	2.9	0.4	0.1
99RME-0098	<3	NA	NA	0.40	5.3	3.29	128	35	3.7	3.8	0.8
99RME-0269	<3	NA	NA	0.21	2.5	1.24	43	18	2.4	1.0	0.3
99RME-0273	<3	NA	NA	0.09	0.7	0.64	22	11	2.0	0.4	0.1
99RME-0386	<3	NA	NA	<0.01	0.4	0.23	8	1	6.8	0.1	0.0
99RME-0388	<3	NA	NA	0.02	0.3	0.34	11	5	2.2	0.2	0.0
99RME-0399	<3	NA	NA	0.07	0.2	0.34	10	4	2.5	0.1	0.0
99RME-0454	<3	NA	NA	0.07	0.3	0.45	15	7	2.1	0.2	0.1
99RME-0459	<3	NA	NA	0.06	0.1	0.26	8	4	2.0	0.0	0.0
99RME-0463	<3	NA	NA	0.06	0.3	0.29	9	4	2.3	0.2	0.0
99RME-0505	<3	NA	NA	<0.01	0.3	0.27	8	4	1.9	0.1	<0.02
99RME-0516	<3	NA	NA	0.89	11.0	1.76	60	15	4.1	2.7	0.5
99RME-0543	<3	NA	NA	<0.01	0.2	0.29	NA	3		0.2	<0.02
99RME-0545	<3	NA	NA	<0.01	0.3	0.40	10	4	2.7	0.1	0.0
99RME-0763	<3	NA	NA	0.54	8.0	3.60	107	31	3.5	3.8	1.0
99RME-0786	<3	NA	NA	0.02	0.4	0.54	15	4	3.5	0.2	0.0
99RME-0787	<3	NA	NA	0.01	0.6	0.41	14	1	10.9	0.2	0.1
99RME-2002	<3	NA	NA	0.06	0.1	0.13	6	1	4.2	0.1	<0.02
99RME-2013	<3	NA	NA	0.07	0.3	0.26	9	2	4.8	0.2	0.0
99RME-2021	<3	NA	NA	0.07	0.4	0.29	12	3	3.6	0.3	0.1
99RME-2026	<3	NA	NA	0.22	0.2	0.65	<1	<0.5		0.3	0.1
99RME-2050	<3	NA	NA	0.05	0.1	0.14	5	3	2.0	0.1	<0.02
99RME-2064	<3	NA	NA	0.06	0.1	0.32	11	7	1.6	0.1	<0.02
99RME-2100	<3	NA	NA	0.09	0.7	0.46	17	7	2.5	0.4	0.1
99RME-2116	<3	NA	NA	0.08	0.4	0.25	9	5	1.7	0.2	0.0
99RME-2147	<3	NA	NA	0.06	0.2	0.28	10	6	1.5	0.2	0.0
99RME-2165	<3	NA	NA	0.07	0.3	0.29	10	5	2.1	0.2	0.0
99RME-2170	<3	NA	NA	0.11	0.8	0.68	22	9	2.5	0.7	0.5
99RME-2190	<3	NA	NA	0.06	0.2	0.25	8	4	1.8	0.1	0.0
99RME-2193	<3	NA	NA	0.05	0.1	0.11	4	3	1.5	0.1	<0.02
99RME-2198	<3	NA	NA	0.10	0.8	0.43	15	4	3.7	0.3	6.0
99RME-2203	<3	NA	NA	0.07	0.3	0.27	10	4	2.4	0.2	0.0
99RME-2213	<3	NA	NA	0.08	0.6	0.40	17	5	3.3	0.4	0.1
99RME-2224	<3	NA	NA	0.11	0.9	0.45	16	9	1.6	0.2	0.1
99RME-2230	<3	NA	NA	0.09	0.8	0.51	20	6	3.4	0.1	0.1
99RME-2240	<3	NA	NA	0.09	0.7	0.51	19	7	2.8	0.1	0.1
99RME-2242	<3	NA	NA	0.08	0.4	0.33	12	4	2.9	0.1	0.1
99RME-2243	<3	NA	NA	0.09	0.7	0.55	21	6	3.8	0.1	0.1
99RME-2244	<3	NA	NA	0.05	0.1	0.10	3	2	1.8	0.1	<0.02
99RME-2249	<3	NA	NA	0.06	0.3	0.30	11	5	2.4	0.1	0.0
99RME-2257	<3	NA	NA	0.12	1.2	0.68	27	10	2.8	0.1	0.1
99RME-2291	<3	NA	NA	NA	0.9	NA	21	9	2.5	NA	NA
99RME-2330	<3	NA	NA	<0.01	0.1	0.22	8	3	2.5	0.1	<0.02

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Sample No.	La ppm	Ce ppm	Pr ppm	Nd ppm	Sm ppm	Eu ppm	Gd ppm	Tb ppm	Dy ppm	Ho ppm	Er ppm	Tm ppm	Yb ppm	Lu ppm	Total REE
98RME-0350	2.61	5.34	0.94	4.75	1.40	0.72	1.69	0.30	1.98	0.45	1.18	0.22	1.31	0.21	23.1
98RME-0351	1.87	3.34	0.51	2.32	0.65	0.35	0.70	0.11	0.86	0.21	0.52	0.09	0.62	0.09	12.2
98RME-0354	4.01	7.65	1.02	4.61	1.04	0.51	1.00	0.18	1.14	0.24	0.64	0.12	0.74	0.10	23.0
99RME-0098	18.88	39.52	4.97	21.27	4.76	1.28	4.84	0.83	5.33	1.16	3.28	0.56	3.32	0.50	110.5
99RME-0269	5.96	12.18	1.76	8.06	2.18	0.80	2.39	0.44	2.85	0.62	1.68	0.28	1.84	0.27	41.3
99RME-0273	3.63	6.81	1.09	4.95	1.33	0.55	1.50	0.27	1.74	0.41	1.04	0.19	1.10	0.17	24.8
99RME-0386	1.40	2.77	0.35	1.31	0.26	0.21	0.24	0.02	0.23	0.04	0.14	<0.01	0.12	<0.01	7.1
99RME-0388	2.47	5.04	0.67	2.86	0.68	0.40	0.68	0.12	0.79	0.18	0.53	0.07	0.54	0.07	15.1
99RME-0399	2.03	3.63	0.49	2.24	0.54	0.26	0.54	0.10	0.67	0.15	0.38	0.08	0.47	0.08	11.7
99RME-0454	2.23	4.53	0.66	3.03	0.76	0.35	0.92	0.16	1.13	0.23	0.65	0.12	0.64	0.10	15.5
99RME-0459	1.46	2.54	0.38	1.63	0.50	0.22	0.47	0.09	0.59	0.12	0.36	0.07	0.39	0.06	8.9
99RME-0463	1.73	3.18	0.47	2.16	0.54	0.38	0.66	0.11	0.71	0.16	0.40	0.08	0.38	0.06	11.0
99RME-0505	1.36	2.78	0.38	1.91	0.51	0.53	0.56	0.09	0.64	0.15	0.44	0.05	0.42	0.06	9.9
99RME-0516	19.16	38.82	5.32	19.66	4.02	1.00	3.42	0.52	2.82	0.57	1.47	0.21	1.17	0.20	98.4
99RME-0543	1.44	2.90	0.41	1.65	0.38	0.23	0.46	0.07	0.57	0.09	0.30	0.03	0.26	0.03	8.8
99RME-0545	0.71	1.92	0.25	1.19	0.33	0.07	0.46	0.08	0.69	0.14	0.46	0.06	0.58	0.09	7.0
99RME-0763	17.43	35.20	4.78	19.36	4.74	1.49	5.09	0.96	5.54	1.31	3.83	0.58	3.72	0.61	104.6
99RME-0786	2.25	4.85	0.66	2.73	0.66	0.38	0.74	0.12	0.80	0.19	0.55	0.07	0.51	0.07	14.6
99RME-0787	0.93	1.83	0.24	0.87	0.19	0.10	0.18	0.01	0.20	0.03	0.12	<0.01	0.09	<0.01	4.8
99RME-2002	1.00	1.77	0.22	0.92	0.20	0.25	0.20	0.03	0.21	0.05	0.14	0.02	0.16	0.02	5.2
99RME-2013	1.13	2.22	0.28	1.13	0.28	0.24	0.21	0.05	0.30	0.08	0.20	0.04	0.20	0.03	6.4
99RME-2021	2.15	3.95	0.51	2.16	0.52	0.32	0.48	0.08	0.55	0.12	0.32	0.06	0.32	0.05	11.6
99RME-2026	1.82	7.30	0.57	4.04	0.29	0.08	0.76	0.04	0.56	0.05	0.20	0.06	0.30	0.06	16.1
99RME-2050	1.39	2.35	0.30	1.31	0.30	0.30	0.34	0.06	0.42	0.09	0.23	0.05	0.26	0.04	7.4
99RME-2064	1.55	3.11	0.49	2.40	0.66	0.31	0.83	0.14	1.05	0.24	0.68	0.11	0.66	0.11	12.3
99RME-2100	3.16	6.32	0.85	3.79	0.90	0.52	1.03	0.17	1.04	0.24	0.63	0.11	0.66	0.09	19.5
99RME-2116	2.64	5.14	0.64	2.81	0.63	0.46	0.69	0.12	0.84	0.17	0.54	0.08	0.50	0.08	15.3
99RME-2147	1.70	3.72	0.51	2.35	0.76	0.42	0.79	0.14	0.94	0.23	0.62	0.10	0.61	0.09	13.0
99RME-2165	1.64	3.54	0.46	2.06	0.52	0.30	0.64	0.11	0.80	0.17	0.50	0.10	0.50	0.08	11.4
99RME-2170	5.59	11.21	1.46	5.95	1.42	0.60	1.39	0.25	1.53	0.34	0.88	0.16	0.95	0.15	31.9
99RME-2190	1.33	2.69	0.38	1.70	0.46	0.32	0.53	0.09	0.67	0.16	0.45	0.07	0.49	0.07	9.4
99RME-2193	1.54	2.76	0.35	1.64	0.36	0.27	0.36	0.07	0.40	0.09	0.23	0.04	0.25	0.05	8.4
99RME-2198	2.71	5.40	0.66	2.99	0.68	0.38	0.62	0.11	0.72	0.15	0.42	0.08	0.40	0.06	15.4
99RME-2203	2.11	4.34	0.52	2.20	0.55	0.47	0.60	0.10	0.68	0.16	0.42	0.08	0.46	0.07	12.8
99RME-2213	2.90	5.89	0.70	2.84	0.67	0.44	0.71	0.11	0.80	0.17	0.45	0.09	0.45	0.07	16.3
99RME-2224	3.32	7.40	1.03	4.59	1.18	0.65	1.28	0.22	1.51	0.33	0.94	0.18	0.88	0.15	23.7
99RME-2230	2.42	5.10	0.66	2.96	0.69	0.42	0.78	0.13	0.87	0.19	0.55	0.09	0.56	0.08	15.5
99RME-2240	4.04	7.81	1.01	4.31	0.91	0.51	0.95	0.16	1.02	0.22	0.61	0.11	0.66	0.10	22.4
99RME-2242	2.15	4.09	0.53	2.21	0.58	0.27	0.54	0.10	0.68	0.16	0.44	0.08	0.48	0.07	12.4
99RME-2243	3.61	7.08	0.88	3.72	0.82	0.38	0.87	0.14	0.86	0.20	0.53	0.10	0.59	0.09	19.9
99RME-2244	1.11	1.99	0.21	0.93	0.16	0.33	0.22	0.03	0.26	0.06	0.18	0.04	0.24	0.04	5.8
99RME-2249	1.79	3.69	0.46	2.09	0.46	0.39	0.58	0.11	0.69	0.16	0.45	0.08	0.44	0.07	11.5
99RME-2257	4.23	8.98	1.16	5.20	1.32	0.59	1.39	0.22	1.57	0.35	0.97	0.16	0.89	0.14	27.2
99RME-2291	2.46	5.54	0.76	3.46	0.96	0.35	1.20	0.22	1.47	0.33	0.93	0.14	0.91	0.15	18.9
99RME-2330	1.12	2.25	0.31	1.18	0.28	0.27	0.36	0.05	0.43	0.09	0.31	0.03	0.31	0.04	7.0

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Sample No.	UTM 17, Easting	NAD83 Northing	Rock Type	Source	SiO_2 wt. %	TiO_2 wt. %	Al_2O_3 wt. %	Fe_2O_3* wt. %	MnO wt. %	MgO wt. %	CaO wt. %
99RME-2343	563307	5165179	norite	7	49.34	0.24	9.65	13.66	0.23	16.34	9.05
99RME-2362	562439	5165754	gabbro	7	47.54	0.13	17.97	11.42	0.16	10.15	9.92
99RME-2371A	559597	5166341	troctolite	8	43.32	0.10	18.30	9.34	0.12	14.06	8.37
JLHS1-S3	559657	5166341	melatroctolite	8	38.30	0.14	7.85	15.10	0.20	23.72	3.70
JLHS2-S1	558643	5165245	gabbronorite	8	50.21	0.13	19.95	8.23	0.13	6.90	10.32
JLHS2-S4	558644	5165393	norite	8	50.81	0.18	18.43	8.92	0.14	7.46	11.19
CZ7-500	558431	5168104	fine-grained gabbro	8	52.51	ND	14.17	13.40	0.17	5.16	8.79
CZ7-1000	558431	5168604	fine-grained gabbro	8	51.85	0.91	14.36	13.09	0.18	5.48	8.96
CZ6-110	558511	5167714	fine-grained gabbro	7	47.03	ND	16.05	10.82	0.15	11.38	10.29
57083	N grid		gabbronorite	9	51.70	0.80	5.74	14.70	0.28	16.80	7.59
57110	N grid		anorthosiite	9	49.50	0.13	27.30	3.37	0.05	2.52	14.30
57127	N grid		gabbronorite	9	50.40	0.25	8.98	13.30	0.22	19.10	6.17
57135	N grid		leucogabbro	9	51.50	0.22	14.60	8.84	0.18	9.84	12.60
57150	N grid		gabbroic anorthosiite	9	51.30	0.17	21.70	5.51	0.10	5.03	11.50
57157	N grid		leucogabbro	9	52.50	0.18	11.50	11.00	0.21	15.20	7.61
56701	Tomrose area		anorthosite	10	49.70	0.19	29.30	1.92	0.03	0.67	13.90
56720	Tomrose area		anorthosite	10	50.20	0.23	25.60	4.75	0.07	2.76	12.60
56723	Tomrose area		anorthosite	10	50.40	0.27	28.00	2.87	0.04	0.94	13.10
56752	Tomrose area		leucogabbro	10	51.90	0.24	14.00	8.61	0.17	11.20	11.70
56817	Tomrose area		gabbroic anorthosite	10	47.00	1.25	20.90	12.30	0.11	3.23	11.60
56857	Tomrose area		gabbronorite	10	49.30	0.66	4.64	24.10	0.37	14.00	4.85
56861	Tomrose area		gabbronorite	10	52.80	0.21	5.42	14.50	0.25	20.00	5.76
568890	Tomrose area		gabbroic anorthosite	10	49.90	0.16	22.20	5.23	0.08	5.70	12.40
56903	Tomrose area		gabbtronorite	10	51.50	0.62	6.75	14.70	0.29	13.40	8.87
56913	Tomrose area		gabbronorite	10	49.40	0.81	3.44	25.60	0.38	15.70	3.65
56959	Tomrose area		gabbroic anorthosite	10	50.60	0.46	23.50	6.02	0.09	2.77	12.40
56998	Tomrose area		gabbroic anorthosite	10	50.30	0.21	24.60	5.04	0.07	3.27	12.40
57001	Tomrose area		anorthosite	10	50.50	0.13	26.00	3.45	0.05	2.88	12.40
57114	Tomrose area		leucogabbro	10	51.10	0.14	18.90	7.19	0.14	7.78	1.10
57467	Tomrose area		leucogabbro	10	51.30	0.29	20.80	7.10	0.11	4.46	12.60
4705	NE Loughrin		leucogabbro	11	52.02	0.31	14.03	9.25	0.17	9.05	11.56
4706	NE Loughrin		leucogabbro	11	52.51	0.31	15.21	8.25	0.16	8.38	11.91
4715	NE Loughrin		gabbroic anorthosite	11	48.13	0.27	26.19	4.96	0.06	2.42	13.71
4754	NE Loughrin		leucogabbro	11	52.19	0.42	14.18	8.96	0.16	8.76	12.08
4770	NE Loughrin		mafic gneiss	11	52.62	0.52	21.54	7.43	0.10	2.05	10.52
4725	NE Loughrin		leucogabbro	11	53.83	0.38	11.69	8.07	0.16	11.08	12.56
Positano	546900	~5160860	leucogabbro	12	50.62	0.23	24.16	5.48	0.09	4.07	12.41
02RME-0106	546920	5160860	leucogabbro	3	50.56	0.28	22.43	6.43	0.11	4.85	12.78
02RME-0054	535389	5162058	amphibolite	3	49.24	0.42	13.66	9.16	0.17	10.42	13.25
02RME-0103	546218	5159775	gabbro	3	51.37	0.40	14.96	8.18	0.16	9.83	14.21
02RME-0370	546969	5158730	gabbronorite	3	52.22	0.50	14.50	10.10	0.18	9.32	12.32
02RME-0371	547011	5158919	gabbronorite	3	51.84	0.45	14.38	9.85	0.18	9.77	12.51
02RME-0602	542795	5156710	amphibolite	3	49.66	0.42	13.72	9.40	0.17	10.66	13.41

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Sample No.	Na_2O wt. %	K_2O wt. %	P_2O_5 wt. %	CO_2 wt. %	S wt. %	LOI wt. %	Total wt. %	Mg-no.	Cr ppm	Ni ppm	Co ppm	Sc ppm	Cu ppm	V ppm
99RME-2343	1.05	0.08	<0.01	0.29	0.02	0.34	99.98	70.3	>500	278	76	29	80	166
99RME-2362	1.93	0.16	0.01	0.19	<0.01	0.06	99.45	63.8	124	287	71	11	59	83
99RME-2371A	1.34	0.28	0.03	0.22	<0.1	4.51	99.77	73.0	1136	595	78	11	16	43
JLHS1-S3	0.70	0.12	0.04	0.22	<0.1	10.12	99.85	73.9	159	1360	155	17	162	48
JLHS2-S1	2.09	0.21	0.03	0.18	<0.1	1.99	100.06	60.2	73	97	41	20	18	71
JLHS2-S4	1.87	0.20	0.03	0.15	<0.1	0.43	99.48	60.1	90	92	38	28	94	109
CZ7-500	2.16	0.85	0.09	0.26	0.02	1.36	98.66	40.9	90	57	50	29	171	284
CZ7-1000	2.25	0.94	0.10	0.22	<0.1	1.60	98.81	43.0	115	75	39	30	401	287
CZ6-110	1.47	0.42	0.04	0.15	<0.01	1.85	99.50	67.6	460	465	75	29	251	125
57083	0.53	0.11	0.11	NA	NA	0.65	99.01	69.4	547	NA	NA	NA	NA	NA
57110	2.09	0.20	0.01	NA	NA	0.65	100.12	59.7	205	NA	NA	NA	NA	NA
57127	0.92	0.14	0.02	NA	NA	0.45	99.95	74.0	1163	NA	NA	NA	NA	NA
57135	1.65	0.13	0.02	NA	NA	0.35	99.93	68.8	547	NA	NA	NA	NA	NA
57150	2.72	0.54	0.02	NA	NA	1.40	99.99	64.4	205	NA	NA	NA	NA	NA
57157	1.33	0.14	0.02	NA	NA	0.25	99.94	73.2	616	NA	NA	NA	NA	NA
56701	3.10	0.24	0.03	NA	NA	0.90	99.98	40.9	<65	NA	NA	NA	NA	NA
56720	2.77	0.39	0.03	NA	NA	0.70	100.10	53.5	137	NA	NA	NA	NA	NA
56723	3.15	0.50	0.04	NA	NA	0.80	100.11	39.3	<65	NA	NA	NA	NA	NA
56752	1.62	0.15	0.02	NA	NA	0.35	99.96	72.0	616	NA	NA	NA	NA	NA
56817	3.07	0.22	0.02	NA	NA	0.25	99.95	34.2	<65	NA	NA	NA	NA	NA
56857	0.46	0.26	0.04	NA	NA	1.00	99.68	53.5	274	NA	NA	NA	NA	NA
56861	0.46	0.11	0.02	NA	NA	0.80	100.33	73.2	753	NA	NA	NA	NA	NA
568890	2.29	0.66	0.02	NA	NA	1.45	100.09	68.3	274	NA	NA	NA	NA	NA
56903	0.66	0.20	0.03	NA	NA	1.45	98.47	64.3	479	NA	NA	NA	NA	NA
56913	0.38	0.24	0.12	NA	NA	<0.15	99.72	54.8	479	NA	NA	NA	NA	NA
56959	2.83	0.42	0.05	NA	NA	1.00	100.14	47.7	137	NA	NA	NA	NA	NA
56998	2.68	0.61	0.03	NA	NA	0.95	100.16	56.2	137	NA	NA	NA	NA	NA
57001	3.19	0.46	0.02	NA	NA	1.05	100.13	62.3	<65	NA	NA	NA	NA	NA
57114	2.25	0.34	0.01	NA	NA	1.20	90.15	68.2	411	NA	NA	NA	NA	NA
57467	2.86	0.30	0.02	NA	NA	0.25	100.09	55.4	137	NA	NA	NA	NA	NA
4705	2.00	0.28	0.03	NA	NA	0.91	99.61	66.2	205	105	40	35	10	145
4706	2.04	0.33	0.03	NA	NA	0.70	99.83	67.0	245	100	35	35	35	130
4715	2.37	0.50	0.03	NA	NA	0.82	99.46	49.4	395	40	15	10	5	75
4754	1.67	0.33	0.03	NA	NA	1.06	99.84	66.2	255	115	35	35	35	170
4770	3.44	0.67	0.12	NA	NA	0.70	99.71	35.6	130	140	20	15	5	125
4725	1.09	0.28	0.16	NA	NA	0.45	99.75	73.3	880	175	35	35	110	170
Positano	3.08	0.28	0.04	NA	NA	0.23	100.69	59.8	NA	NA	NA	17	NA	NA
02RME-0106	2.51	0.28	0.02	0.08	0.02	0.60	100.87	59.9	34	83	37	22	48	109
02RME-0054	1.75	0.30	0.03	0.98	0.02	0.56	98.98	69.4	21	162	49	39	25	191
02RME-0103	1.29	0.37	0.03	0.08	0.10	0.04	100.94	70.5	1299	169	48	37	66	185
02RME-0370	1.51	0.37	0.04	0.09	0.02	0.31	101.39	64.6	257	134	46	36	157	186
02RME-0371	1.46	0.31	0.03	0.10	0.04	0.17	100.99	66.3	224	139	48	37	160	182
02RME-0602	1.46	0.30	0.03	0.07	0.50	0.55	100.28	69.2	498	159	45	36	115	180

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Sample No.	Au ppb	Pd ppb	Pt ppb	PGE ppb	Pb ppm	Zn ppm	Mo ppm	W ppm	Sn ppm	As ppm	Rb ppm	Cs ppm	Ba ppm	Sr ppm
99RME-2343	7	<8	<8	7	10	112	<1	NA	NA	NA	1	0.03	36	119
99RME-2362	<5	<8	<8	<21	1	97	<1	NA	NA	NA	1	<0.01	85	163
99RME-2371A	<5	<8	<8	<21	NA	92	<8	NA	NA	NA	4	NA	93	235
JLHS1-S3	<5	11	10	21	NA	111	<8	NA	NA	NA	5	0.26	79	104
JLHS2-S1	<5	19	<8	19	NA	56	<8	NA	NA	NA	4	0.17	139	265
JLHS2-S4	<5	29	11	40	NA	66	<8	NA	NA	NA	2	0.07	121	247
CZ7-500	<5	19	18	36	NA	109	<8	NA	NA	NA	38	0.39	341	327
CZ7-1000	6	25	18	49	NA	108	<8	NA	NA	NA	36	0.39	251	210
CZ6-110	<5	38	18	56	NA	72	<8	NA	NA	NA	13	0.44	136	205
57083	NA	NA	NA		NA	NA	NA	NA	NA	NA	3	NA	23	12
57110	NA	NA	NA		NA	NA	NA	NA	NA	NA	4	NA	87	305
57127	NA	NA	NA		NA	NA	NA	NA	NA	NA	6	NA	66	104
57135	NA	NA	NA		NA	NA	NA	NA	NA	NA	7	NA	86	156
57150	NA	NA	NA		NA	NA	NA	NA	NA	NA	8	NA	113	278
57157	NA	NA	NA		NA	NA	NA	NA	NA	NA	4	NA	76	154
56701	NA	NA	NA		NA	NA	NA	NA	NA	NA	6	NA	94	327
56720	NA	NA	NA		NA	NA	NA	NA	NA	NA	6	NA	98	317
56723	NA	NA	NA		NA	NA	NA	NA	NA	NA	9	NA	110	343
56752	NA	NA	NA		NA	NA	NA	NA	NA	NA	6	NA	69	157
56817	NA	NA	NA		NA	NA	NA	NA	NA	NA	4	NA	99	302
56857	NA	NA	NA		NA	NA	NA	NA	NA	NA	12	NA	76	61
56861	NA	NA	NA		NA	NA	NA	NA	NA	NA	5	NA	54	52
568890	NA	NA	NA		NA	NA	NA	NA	NA	NA	16	NA	90	268
56903	NA	NA	NA		NA	NA	NA	NA	NA	NA	8	NA	40	40
56913	NA	NA	NA		NA	NA	NA	NA	NA	NA	14	NA	70	34
56959	NA	NA	NA		NA	NA	NA	NA	NA	NA	8	NA	122	276
56998	NA	NA	NA		NA	NA	NA	NA	NA	NA	10	NA	112	259
57001	NA	NA	NA		NA	NA	NA	NA	NA	NA	7	NA	94	364
57114	NA	NA	NA		NA	NA	NA	NA	NA	NA	6	NA	63	230
57467	NA	NA	NA		NA	NA	NA	NA	NA	NA	4	NA	94	275
4705	NA	NA	NA		NA	125	NA	NA	NA	NA	<100	NA	90	190
4706	NA	NA	NA		NA	95	NA	NA	NA	NA	<100	NA	110	210
4715	NA	NA	NA		NA	65	NA	NA	NA	NA	<100	NA	60	350
4754	NA	NA	NA		NA	135	NA	NA	NA	NA	<100	NA	80	90
4770	NA	NA	NA		NA	155	NA	NA	NA	NA	100	NA	150	310
4725	NA	NA	NA		NA	10	NA	NA	NA	NA	<100	NA	40	80
Positano	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA	95	315
02RME-0106	49	2.3	14.6	66	<8	50	<8	5	6	<2	2	0.15	312	276
02RME-0054	<6	<2	3.3	3	<8	78	<8	<2	5	<2	8	0.29	804	115
02RME-0103	560	<2	1.3	561	<8	60	<8	<2	<5	<2	9	0.40	316	113
02RME-0370	<6	<2	3.9	4	9	69	<8	<2	<5	<2	11	0.55	90	110
02RME-0371	<6	<2	1.8	2	7	69	<8	<2	<5	<2	8	0.40	77	96
02RME-0602	10	8.9	13.0	31	8	62	<8	<2	<5	<2	7	0.12	53	99

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Sample No.	Be ppm	Ga ppm	Li ppm	Ta ppm	Nb ppm	Hf ppm	Zr ppm	Y ppm	Zr/Y	Th ppm	U ppm
99RME-2343	<3	NA	NA	<0.01	0.1	0.31	8	6	1.2	0.0	<0.02
99RME-2362	<3	NA	NA	<0.01	0.1	0.21	7	3	2.6	0.1	<0.02
99RME-2371A	<3	NA	NA	NA	0.3	NA	7	4	1.8	NA	NA
JLHS1-S3	<3	NA	NA	<0.30	0.7	0.41	15	3	4.9	0.5	0.1
JLHS2-S1	<3	NA	NA	<0.30	0.1	0.16	<6.0	3		0.1	0.0
JLHS2-S4	<3	NA	NA	<0.30	0.2	0.26	8	5	1.7	0.1	0.0
CZ7-500	<3	NA	NA	<0.30	3.5	2.98	98	19	5.1	6.5	0.7
CZ7-1000	<3	NA	NA	<0.30	4.1	2.10	68	17	3.9	3.9	0.4
CZ6-110	<3	NA	NA	<0.30	1.0	0.83	27	9	3.1	0.6	0.2
57083	NA	NA	NA	NA	2.0	NA	44	11	4.0	NA	NA
57110	NA	NA	NA	NA	<2	NA	7	<2		NA	NA
57127	NA	NA	NA	NA	<2	NA	13	5	2.6	NA	NA
57135	NA	NA	NA	NA	<2	NA	10	5	2.0	NA	NA
57150	NA	NA	NA	NA	<2	NA	11	<2		NA	NA
57157	NA	NA	NA	NA	<2	NA	13	<2		NA	NA
56701	NA	NA	NA	NA	2.0	NA	16	3	5.3	NA	NA
56720	NA	NA	NA	NA	2.0	NA	18	2	9.0	NA	NA
56723	NA	NA	NA	NA	4.0	NA	24	4	6.0	NA	NA
56752	NA	NA	NA	NA	<2	NA	15	6	2.5	NA	NA
56817	NA	NA	NA	NA	<2	NA	13	2	6.5	NA	NA
56857	NA	NA	NA	NA	<2	NA	28	11	2.5	NA	NA
56861	NA	NA	NA	NA	<2	NA	8	5	1.6	NA	NA
568890	NA	NA	NA	NA	<2	NA	12	<2		NA	NA
56903	NA	NA	NA	NA	<2	NA	23	11	2.1	NA	NA
56913	NA	NA	NA	NA	<2	NA	29	15	1.9	NA	NA
56959	NA	NA	NA	NA	<2	NA	33	7	4.7	NA	NA
56998	NA	NA	NA	NA	<2	NA	16	2	8.0	NA	NA
57001	NA	NA	NA	NA	<2	NA	9	2	4.5	NA	NA
57114	NA	NA	NA	NA	<2	NA	7	2	3.5	NA	NA
57467	NA	NA	NA	NA	<2	NA	16	4	4.0	NA	NA
4705	<5	NA	NA	NA	<10	NA	20	5	4.0	NA	NA
4706	<5	NA	NA	NA	<10	NA	20	5	4.0	NA	NA
4715	<5	NA	NA	NA	<10	NA	20	5	4.0	NA	NA
4754	<5	NA	NA	NA	<10	NA	30	10	3.0	NA	NA
4770	<5	NA	NA	NA	<10	NA	70	25	2.8	NA	NA
4725	<5	NA	NA	NA	<10	NA	30	10	3.0	NA	NA
Positano	NA	NA	NA	NA	NA	NA	16	4	4.0	NA	NA
02RME-0106	0.1	17	<2	0.17	0.7	0.44	14	7	2.0	0.4	0.1
02RME-0054	0.2	19	<2	0.22	1.3	0.76	27	11	2.4	1.0	0.3
02RME-0103	0.1	8	<2	0.19	1.2	0.89	29	11	2.7	0.9	0.3
02RME-0370	0.1	15	<2	0.24	1.7	1.26	40	14	2.9	1.3	0.4
02RME-0371	0.1	13	<2	0.21	1.4	1.06	33	13	2.5	1.1	0.4
02RME-0602	<0.10	13	<2	<0.17	1.3	0.79	29	13	2.2	1.0	0.3

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Sample No.	La ppm	Ce ppm	Pr ppm	Nd ppm	Sm ppm	Eu ppm	Gd ppm	Tb ppm	Dy ppm	Ho ppm	Er ppm	Tm ppm	Yb ppm	Lu ppm	Total REE
99RME-2343	0.88	2.14	0.33	1.66	0.50	0.26	0.77	0.10	0.92	0.22	0.67	0.10	0.74	0.11	9.4
99RME-2362	1.17	2.29	0.28	1.17	0.28	0.29	0.36	0.04	0.39	0.10	0.27	0.03	0.28	0.04	7.0
99RME-2371A	2.66	5.42	0.64	2.40	0.49	0.29	0.49	0.06	0.36	0.07	0.20	0.03	0.20	0.03	13.3
JLHS1-S3	2.13	4.40	0.57	2.31	0.50	0.19	0.46	0.08	0.51	0.10	0.32	0.05	0.38	0.06	12.1
JLHS2-S1	1.26	2.34	0.30	1.33	0.34	0.35	0.36	0.06	0.46	0.11	0.35	0.06	0.38	0.06	7.8
JLHS2-S4	1.49	3.20	0.44	2.01	0.51	0.35	0.67	0.12	0.77	0.18	0.56	0.08	0.56	0.08	11.0
CZ7-500	27.55	58.77	7.03	26.25	4.76	1.05	3.85	0.55	3.30	0.71	1.96	0.28	1.80	0.29	138.2
CZ7-1000	20.73	44.46	5.32	19.92	3.79	0.88	3.13	0.49	3.04	0.64	1.81	0.27	1.78	0.28	106.5
CZ6-110	4.11	8.75	1.18	5.01	1.18	0.48	1.35	0.22	1.45	0.32	0.97	0.14	0.86	0.15	26.2
57083	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
57110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
57127	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
57135	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
57150	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
57157	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
56701	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
56720	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
56723	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
56752	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
56817	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
56857	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
56861	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
568890	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
56903	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
56913	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
56959	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
56998	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
57001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
57114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
57467	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
4705	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
4706	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
4715	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
4754	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
4770	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
4725	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Positano	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
02RME-0106	3.00	6.29	0.83	3.53	0.97	0.50	1.12	0.17	1.18	0.26	0.76	0.11	0.71	0.12	19.5
02RME-0054	3.82	8.37	1.07	4.44	1.28	0.48	1.67	0.30	1.96	0.43	1.20	0.19	1.19	0.19	26.6
02RME-0103	3.48	7.63	1.01	4.27	1.22	0.50	1.64	0.29	1.88	0.41	1.18	0.18	1.20	0.17	25.1
02RME-0370	5.20	11.16	1.49	6.13	1.69	0.64	2.11	0.36	2.31	0.53	1.48	0.22	1.44	0.24	35.0
02RME-0371	4.43	9.54	1.25	5.17	1.32	0.54	1.76	0.34	2.05	0.47	1.32	0.22	1.18	0.19	29.8
02RME-0602	3.83	8.28	1.07	4.43	1.28	0.50	1.66	0.32	1.96	0.45	1.27	0.20	1.24	0.19	26.7

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 3. Listing of geochemical data on East Bull Lake intrusive suite rock units in the study area — continued.

Source number in Appendix 3	Reference
1	Easton 1998; Easton and Murphy 2002; Easton and Hrominchuk 2002
2	Easton and Murphy 2002; Easton and Hrominchuk 2002
3	New data from this study
4	Hubbard 1998; Easton and Hrominchuk 2002
5	Dressler 1979; Easton and Hrominchuk 2002
6	Easton and Hrominchuk 1999, 2002
7	Easton and Murphy 2002; Easton and Hrominchuk 2002
8	Hrominchuk 2000; Easton and Hrominchuk 2002
9	Mustang Minerals Corporation in Sudbury Assessment File Dana SP-008
10	Mustang Minerals Corporation in Sudbury Assessment File Crerar SP-008
11	Mustang Minerals Corporation in Sudbury Assessment File Loughrin SP-006
12	Kirwan (1992)

Comment: Data for samples 02RME-0014, -0018, -0030, -0070, -0097, -0103, -0106 and -0156 originally appeared in table 15.2 in Easton (2002b). These samples were contaminated with an ore sample, and were subsequently re-analyzed. The data reported in this appendix are from these re-analyzed samples. Apart from some metallic elements and the platinum group elements, there was little change in most elemental contents between the contaminated and uncontaminated samples. Nonetheless, the data presented herein is preferred over the data presented in Table 15.2 in Easton (2002b).

Abbreviations: anth = anthophyllite; CIA = chemical index of alteration,; cgr = coarse-grained; ep = epidote; hb = hornblende; NA = not analyzed; ND = no data; opx = orthopyroxene; PGE = total Au+Pd+Pt for the sample. List of sources is given at end of this appendix. Numbers preceded by a less than sign indicates that the element was below the detection limit given by the number, e.g. <5 ppm Cu means that the sample contained less than the 5 ppm detection limit for copper. As samples were analyzed over a 3-year period, detection limits will vary between samples.

Appendix 4.

Summary of Stratigraphic and Other Data for the East Bull Lake Intrusive Suite.

Appendix 4. Summary of stratigraphic, mineralogical and geochemical data for the East Bull Lake intrusive suite (modified from James et al. 2002a).

Intrusion	Size (km^2)	Dominant Rock Types	Metamorphic Grade	Geochemisty √ = data available				Primary Mineral Chemistry	Contact relationships	Stratigraphic Thickness	Location of Reference Sections, UTM Zone 17, NAD 83	References
				Major	Trace	REE	Isotope					
Southern Province hosted intrusions												
Agnew Lake *or* Shakespeare -Dunlop	50	Leucogabbronorite gabbronorite, olivine gabbronorite.	Upper greenschist to lower amphibolite	√ n=~100	√	√	√	Plag = An_{2-79}	Ramsey-Algoma granitoid complex rocks in footwall, diking and brecciation in footwall at contacts, to east, possible unconformable contact with Huronian Sgp. metasedimentary rocks.	at least 1000 m, as much as 2100 m in some interpretations	Not defined	Vogel 1996; Vogel, James and Keays 1998; Vogel et al. 1999
Drury Twp. *or* Worthington	8-10	Leucogabbro, gabbro.	Shock metamorphosed, locally upper greenschist, remelted(?)	√ n=~10	√ n = 5	√ n=5	√ n=5	No data	Contacts typically zones rich in Sudbury breccia. Intrusion in contact aureole of the Sudbury Igneous Complex.	Unknown	Not defined	Brons 1984; Prevec 1993
East Bull Lake, *includes* outliers at Splake and Tee Lakes	43	Leucogabbronorite gabbronorite, olivine gabbronorite.	Lower to upper greenschist	√ n=~200	√	√	√	Plag = An_{60-80} Rhytmically layered zone: ol = Fo_{59-65}, opx = $En_{64-66}Fs_{30-32}Wo_{4}$, cpx = $En_{41-45}Fs_{15-16}Wo_{39-44}$ Olivine gabbronorite zone: ol = Fo_{65-74} opx = $En_{67-706}Fs_{26-29}Wo_{4}$, cpx = $En_{41-43}Fs_{14-15}Wo_{43-44}$	Parisien Lake syenite, Whiskey Lake greenstone belt, Ramsey-Algoma granitoid complex rock, diking and brecciation in footwall at contacts, possible unconformable contact with Huronian Supergroup metasediments to the north.	~850 m	Not defined	Born 1979; James and Born 1985; McCrank et al. 1989; Peck, James and Chubb 1993; Peck et al. 1995; Prevec 1993; Vogel, James and Keays 1998
Falconbridge Twp. *or* Norduna	1-2	Leucogabbronorite gabbronorite.	Shock metamorphosed, upper greenschist	√ n = 8	√ n = 8	√ n=8	√ n=8	Plag = An_{60-76}	Contacts typically zones rich in Sudbury breccia. Intrusion located in contact aureole of the Sudbury Igneous Complex.	Unknown	Not defined	DeGagne 1982; Prevec 1993
May Twp. *or* Salmay Lake	15	Leucogabbro, gabbro, melanogabbro.	Lower to upper greenschist	√ n = ~15	√ n = 5	√ n=5	√ n=5	No data	Melanogabbro better preserved than leucocratic rocks.	Unknown	Not defined	Cape 1973; Robertson 1976; Prevec 1993
Wisner Twp.	~5	Leucogabbronorite	Shock metamorphosed, upper greenschist?					No data	unknown	Unknown	Not defined	Vogel, James and Keays 1998

Appendix 4. continued

Intrusion	Size (km^2)	Dominant Rock Types	Metamorphic Grade	Geochemisty √ = data available				Primary Mineral Chemistry	Contact relationships	Stratigraphic Thickness	Location of Reference Sections, UTM Zone 17, NAD 83	References
				Major	Trace	REE	Isotope					
Grenville Province hosted intrusions												
River Valley	~100	Leucogabbronorite gabbronorite, olivine gabbronorite.	Greenschist to upper amphibolite, with some areas of primary mineralogy preserved, mainly in Dana Township.	√ n = ~70	√ ~70	√ ~70		Marginal zone: Plag = An_{79} (core); An_{68}, (intercumulate) Olivine gabbronorite zone: ol = Fo_{74} plag = An_{70-75} opx = En_{60-80}	***Primary Contacts: Dana Twp.:*** Sharp contact with paragneiss or alkali feldspar granite, no dikes in footwall, marginal zone contains footwall xenoliths. Fault contacts with Huronian Sgp. metasedimentary and metavolcanic rocks, equivocal contact with Nipissing gabbro. ***Crerar Twp:*** Sharp contact with alkali feldspar granite, alteration of granite in footwall, fine-grained phase at contact, no dikes in footwall, marginal zone contains footwall xenoliths. Hosted by Crerar gneiss association.	~1000 m	Marginal zone: 555310E, 5172625N; 556610E, 5174225N to 556510E, 5171225N; 558760E, 5167825N to 558510E, 5167475N. Olivine Gabbronorite zone: 559260E, 516825N; 563260E, 5166225N; 560410E, 5167825N. Gabbronorite zone: 558510E, 5165575N	Easton and Hrominchuk 1999; Hrominchuk 1999, 2000
Loughrin Lake	~25	Gneissic leucogabbronorite, gabbronorite, associated orthopyroxene hornblendite.	Upper amphibolite	√ n = 12	√ n = 11	√ n = 5		No data	North contact mainly tectonic. South contact sharp, with scattered orthopyroxene hornblendite bodies. Hosted by Street gneiss association.	~500 to 1000 m	Not defined	This study
Third Concession	~5	Gneissic leucogabbronorite, gabbronorite, associated orthopyroxene hornblendite.	Upper amphibolite	√ n = 1	√ n = 1	√ n = 1		No data	North contact locally cut by Geon 24 to 23 felsic intrusions. South contact sharp, with scattered opx hornblendite bodies. Both contacts locally intrude migmatitic garnet amphibolite. Hosted by Street gneiss association.	~500 m	Not defined	This study

Appendix 4. continued

Intrusion	Size (km^2)	Dominant Rock Types	Metamorphic Grade	Geochemisty √ = data available				Primary Mineral Chemistry	Contact relationships	Stratigraphic Thickness	Location of Reference Sections, UTM Zone 17, NAD 83	References
				Major	Trace	REE	Isotope					
Contact	~5	Gneissic, leucogabbronorite, gabbronorite, associated orthopyroxene hornblendite.	Upper amphibolite					No data	North contact locally cut by Geon 24 to 23 felsic intrusions. South contact sharp, with scattered orthopyroxene hornblendite bodies. Hosted by Street and Crerar gneiss association.	less than 500 m	Not defined	This study
Street metagabbro	~5	Leucogabbronorite gabbronorite, norite, associated orthopyroxene hornblendite.	Upper amphibolite	√ n = 25	√ n=25	√ n=25		Coronitic orthopyroxene present	Basal contact intrudes migmatitic garnet amphibolite, ~2475 Ma granites contain fragments of intrusion. Hosted by Street gneiss association.	less than 500 m	530510E, 5155225 to 5155725N	Easton 1999a; Easton and Murphy 2002
Red Deer Lake	~10	Gneissic leucogabbro, gabbro, norite.	Upper amphibolite	√ n = 1				No data	Unknown	Unknown	Not defined	Lumbers 1975
Southern Wanapitei Complex	~5	Gneissic leucogabbronorite, gabbronorite.	Upper amphibolite	√ n = 8				Coronitic olivine present	Unknown	Unknown	Not defined	Rousell and Trevisiol 1988

Appendix 5.

Listing of Assay Data from the Study Area.

Some of these data were previously published by Easton and Hrominchuk (1999, 2002).

Appendix 5. Assay data from samples from the study area, with an emphasis on the River Valley intrusion, Crerar and Dana townships.

Sample number	UTM 17T, NAD 83		Field Rock Name	Visible Sulphide	Cr (4)	Ni (5)	Co (5)	Cu (5)	Ti (3)	Au (5)	Pt (8)	Pd (8)	Pt/Pd	Au+ Pt+ Pd
	Easting	Northing			ppm					ppb				
Dana North area														
Road zone (Occurrence 8a, Map P.3433)														
98RME-0350	555260	5172689	gabbro		102	145	38	502	4257	22	162	427	0.4	589
Trench Zone (Occurrence 8c, Map P.3433)														
98RME-0351	555260	5172689	gabbro	X	170	308	57	698	801	<5	<8	<8		
98RME-0351-#1	555260	5172689	gabbro		229	276	59	631	1063	24	179	476	0.4	655
Northeast of Road zone														
99RME-0269	556560	5172664	gabbro		255	148	50	117	2698	<5	13	15	0.9	28
99RME-0273	556490	5173714	gabbro		75	95	45	142	4736	<5	62	133	0.5	195
South of south zone (Occurrence 3, Map. P.3433)														
99RME-0243	555710	5171764	mylonite	X	291	123	34	87	4183	<5	<8	<8		
99RME-0244	555640	5171704	gabbro	X	250	749	79	3729	811	144	1079	2799	0.4	4022
99RME-0245	555685	5171734	gabbro	X	59	60	47	83	7172	13	44	48	0.9	105
East of south zone														
99RME-0240	556250	5171894	mafic mylonite	X	40	41	55	631	8935	9	19	19	1.0	47
99RME-0241	556140	5171814	mafic mylonite	X	100	64	41	228	6028	<5	17	13	1.3	30
Southern-Grenville Province boundary zone														
99RME-0200	555457	5169387	leucogabbro		77	228	40	35	651	<5	<8	<8		
99RME-0202	560614	5165882	Mafic mylonite	X	106	80	54	401	5575	17	17	19	0.9	53
99RME-0613	555650	5171046	fgr gabbro	X	181	375	98	1645	N.A.	170	139	106	1.39	415
Dana 1 occurrence (Occurrence 8f, Map P.3433)														
99RME-2086	558488	5168389	leucogabbro		152	158	45	389	2952	12	49	88	0.6	149
99RME-2087	558572	5168794	leucogabbro	X	95	217	49	769	5636	371	864	2348	0.4	3583
Dana 2 occurrence (Occurrence 4, Map P.3433)														
99RME-0486	555160	5170709	leucogabbro	X	108	40	21	80	1040	44	66	44	1.5	154
99RME-0487	555010	5170689	leucogabbro	X	42	63	24	92	1411	52	150	121	1.2	323
99RME-0488	555115	5170544	leucogabbro	X	100	41	19	91	892	35	83	84	1.0	202
99RME-0489	555175	5170524	leucogabbro	X	56	60	25	323	3470	<5	<8	11		11
99RME-0490	555190	5170434	leucogabbro	X	94	59	27	874	4032	8	38	28	1.4	74
Azen Zone (Occurrence 8g, Map P.3433)														
98RME-0354	559170	5167674	leucogabbro overlying mineralization		231	150	30	114	1199	9	19	9	2.1	28
99RME-2240	559170	5167680	leucogabbro		169	135	28	119	1500	<5	<8	<8		
99RME-2242-#1	559170	5167678	gabbronorite	X	203	1840	119	4512	959	145	576	1980	0.3	2701
99RME-2242-#2	559170	5167678	pyroxene troctolite	X	231	1476	103	4393	968	99	494	1404	0.4	1997
99RME-2243	559170	5167677	gabbro	X		623	65	1320	1259	59	106	293	0.4	458

X indicates sulphides present. Other abbreviations as in Appendix 3.

Appendix 5. —continued.

Sample number	UTM 17T, NAD 83		Field Rock Name	Visible Sulphide	Cr (4)	Ni (5)	Co (5)	Cu (5)	Ti (3)	Au (5)	Pt (8)	Pd (8)	Pt/Pd	Au+ Pt+ Pd
	Easting	Northing			Ppm					ppb				
Non-mineralized River Valley intrusion samples, Dana Twp., north of Sturgeon River														
Marginal zone samples														
99RME-2072	560833	5168170	gabbro		380	172	41	71	1697	<5	16	11	1.5	27
99RME-2073	560923	5168194	gabbro		149	142	47	51	1626	<5	8	20	0.4	28
99RME-2075	560526	5168211	gabbro		610	275	64	126	1652	<5	11	<8		11
99RME-2170	558950	5167673	gabbro	X	156	139	32	52	1739	<5	11	11	1.0	22
Vari-textured to massive zone samples														
99RME-2040	560850	5166643	gabbroic anothosite		72	41	14	25	482	<5	24	27	0.9	51
99RME-2046	560690	5166422	gabbronorite	X	150	203	58	43	782	<5	8	42	0.2	50
99RME-2050	560722	5166993	gabbro		87	257	52	65	600	<5	<8	8		
99RME-2064	560495	5167369	gabbro		>500	185	46	36	1200	<5	<8	<8		
99RME-2116	556345	5166811	gabbroic anorthosite		138	44	13	46	959	5	15	19	0.8	39
99RME-2165	557093	5167523	gabbro		306	322	70	68	1079	<5	20	16	1.3	36
99RME-2203	558905	5166311	leucogabbro		50	66	29	45	2098	<5	16	19	0.8	35
99RME-4007	556016	5166647	leucogabbro	X	87	130	28	41	572	<5	<8	<8		
Olivine gabbronorite zone samples														
99RME-2190	558228	5166031	norite		223	181	54	62	839	7	34	37	0.9	78
99RME-2193	557982	5166158	olivine gabbro		136	385	66	21	600	<5	<8	<8		
Layered gabbronorite zone samples														
99RME-2002	560505	5166027	anorthosite		40	138	29	21	420	<5	10	85	0.1	95
99RME-2003	560614	5165882	anorthosite		50	15	<5	28	611	<5	<8	<8		
99RME-2013	560947	5165965	anorthosite		39	52	17	21	719	<5	18	9	2.0	27
99RME-2018	560527	5166244	anorthosite		79	30	10	14	525	<5	<8	<8		
99RME-2021	560920	5166379	anorthosite		69	48	18	23	839	<5	13	<8		13
99RME-2022	561134	5166546	gabbroic anorthosite		222	90	20	39	633	<5	<8	12		12
99RME-2026-#1	560246	5165420	gabbroic anorthosite		345	49	17	23	860	<5	12	25	0.5	24
99RME-2026-#2	560246	5165420	gabbroic anorthosite		<1	41	17	16	1019	<5	14	<8		14
99RME-2028	560520	5165558	leucogabbro		98	28	9	81	640	<5	9	<8		34
99RME-2034	560343	5166357	leucogabbro		96	18	10	37	769	<5	8	<8		8
99RME-2244	558521	5165429	gabbroic anorthosite		86	83	28	18	600	<5	<8	<8		
99RME-2249	560106	5165390	leucogabbro		65	75	26	40		<5	11	16	0.7	27

Appendix 5. —continued.

Sample number	UTM 17T, NAD 83		Field Rock Name	Visible Sul phide	Cr (4)	Ni (5)	Co (5)	Cu (5)	Ti (3)	Au (5)	Pt (8)	Pd (8)	Pt/Pd	Au+ Pt+ Pd
	Easting	Northing			ppm					ppb				
River Valley intrusion, stratigraphically unassigned samples														
99RME-2079	558594	5167681	leucogabbro		88	279	70	236	3046	8	28	61	0.5	97
99RME-2097	558273	5168764	leucogabbro		90	69	29	102	1779	7	26	87	0.3	120
99RME-2099	558212	5168764	leucogabbro		250	99	37	91	1652	<5	26	27	1.0	53
99RME-2099-#2	558212	5168764	leucogabbro		N.A.	N.A.	N.A.	N.A.	N.A.	32	13	<5		45
99RME-2100	558028	5169105	gabbroic anorthosite		245	71	19	84	1800	<5	9	11	0.8	20
99RME-2137	559327	5167443	pyroxenite		212	334	109	647	1150	<5	<8	<8		
99RME-2147	558946	5166224	norite		219	109	36	49	1079	<5	9	<8		9
99RME-2198	559324	5166635	gabbroic anorthosite		30	196	33	51	2098	<5	8	9	0.9	17
99RME-2213	558351	5164835	gabbroic anorthosite		112	60	23	72	1139	<5	50	70	0.7	120
99RME-2224	560630	5164117	gabbro		58	39	24	116	3237	<5	13	<8		13
99RME-2230	560687	5165809	leucogabbro		160	32	14	47	1439	<5	<8	<8		
99RME-2257	560134	5164654	gabbro		35	41	22	78	2758	<5	14	10	1.4	24
99RME-2279	561010	5163354	oxide gabbro	X	119	122	63	45	12660	<5	<8	<8		
99RME-2282	561276	5163864	oxide gabbro		408	70	24	57	1706	<5	<8	<8		
99RME-2301	561410	5163024	oxide gabbro	X	52	90	53	55	15110	<5	<8	<8		
99RME-2319	562059	5166500	gabbronorite	X	136	131	36	421	2580	9	12	50	0.2	71
99RME-2339	563477	5164630	gabbronorite	X	46	56	19	34	610	<5	<8	<8		
99RME-2344	563304	5165181	opx troctolite		495	322	94	93	865	<5	19	17	1.1	36
99RME-2374	558652	5167540	norite	X	282	427	119	920	2209	13	33	33	1.0	79
99RME-2376	558490	5167524	norite	X	246	98	31	63	1372	<5	<8	<8		
99RME-2378	558490	5167364	gabbronorite	X	185	692	103	2220	968	23	102	116	0.9	241
99RME-2445	558930	5165644	leucogabbro	X	114	369	90	1994	3570	<5	14	28	0.5	42
JLHS1-S2	559291	5166377	troctolite		N.A.	N.A.	N.A.	N.A.	N.A.	<8	<8	<5		
JLHS1-S3	559656	5166341	melatroctolite		159	1360	155	162	8393	11	10	<5		21
JLHS1-S4	559313	5166605	olivine norite		N.A.	N.A.	N.A.	N.A.	N.A.	<8	<8	<5		
JLHS1-S5	559323	5166624	quartz notite		N.A.	N.A.	N.A.	N.A.	N.A.	<8	<8	<5		
JLH-2071	558537	5167663	olivine norite		N.A.	N.A.	N.A.	N.A.	N.A.	13	<8	<5		13
JLHS2-S1	558642	5165265	gabbronorite		73	97	41	18	7794	19	<8	<5		19
JLHS2-S2	558672	5165274	gabbronorite		N.A.	N.A.	N.A.	N.A.	N.A.	<8	<8	<5		
JLHS2-S3	558641	5165322	leucogabbro		N.A.	N.A.	N.A.	N.A.	N.A.	9	<8	<5		9
JLHS2-S4	558643	5165393	norite		90	92	38	94	10791	29	11	<5		40
JLHS2-S5	558559	5165392	gabbronorite		N.A.	N.A.	N.A.	N.A.	N.A.	<8	<8	<5		
JLHS2-S6	558575	5165472	leucogabbro		N.A.	N.A.	N.A.	N.A.	N.A.	13	<8	<5		13
99RME-2016	560540	5165838	melagabbro-norite		N.A.	N.A.	N.A.	N.A.	N.A.	96	12	<5		108
99RME-2077	560440	5168019	norite		N.A.	N.A.	N.A.	N.A.	N.A.	<8	<8	<5		

Appendix 5. —continued.

Sample number	UTM 17T, NAD 83		Field Rock Name	Visible Sul phide	Cr (4)	Ni (5)	Co (5)	Cu (5)	Ti (3)	Au (5)	Pt (8)	Pd (8)	Pt/Pd	Au+ Pt+ Pd
	Easting	Northing			ppm					ppb				
River Valley intrusion, stratigraphically unassigned samples, continued														
99RME-2159	558926	5166398	noritic anorthosite		N.A.	N.A.	N.A.	N.A.	N.A.	10	11	6	1.9	27
99RME-2269	559545	5165414	coronitic troctolite		N.A.	N.A.	N.A.	N.A.	N.A.	36	28	<5		64
99RME-2292	560750	5162764	opx olivine gabbro		N.A.	N.A.	N.A.	N.A.	N.A.	12	19	10	1.8	41
99RME-2371A	559596	5166341	troctolite		1136	595	78	16	5995	<8	<8	<5		
99RME-2432	557130	5169124	leucogabbro		N.A.	N.A.	N.A.	N.A.	N.A.	11	<8	<5		11
CZ42-275NE	558254	5169052	gabbro		N.A.	N.A.	N.A.	N.A.	N.A.	333	87	26	3.3	446
CZ44-150NE	558309	5168822	gabbro		N.A.	N.A.	N.A.	N.A.	N.A.	<8	<8	<5		
CZ45-87NE	558340	5168713	gabbro		N.A.	N.A.	N.A.	N.A.	N.A.	242	106	32	3.3	379
CZ7-500	558430	5168104	fgr gabbro		90	57	50	171	5575	19	18	<5		36
CZ7-700	558390	5168304	norite		N.A.	N.A.	N.A.	N.A.	N.A.	38	22	<5		59
CZ7-800	558420	5168389	pyroxenite		N.A.	N.A.	N.A.	N.A.	N.A.	<8	13	7	1.9	19
CZ7-1000	558430	5168604	fgr gabbro		115	75	39	401	4965	25	18	6	3.3	49
DL1-U	558660	5165272	gabbronorite		N.A.	N.A.	N.A.	N.A.	N.A.	9	<8	<5		9
DL1-B	558660	5165273	gabbronorite		N.A.	N.A.	N.A.	N.A.	N.A.	<8	<8	<5		
CZ39-300NE	558061	5169282	gabbro		N.A.	N.A.	N.A.	N.A.	N.A.	16	12	<5		27
CZ41-250NE	558177	5169115	gabbro		N.A.	N.A.	N.A.	N.A.	N.A.	540	104	<5		643
CZ6-110	558510	5167714	fgr gabbro		460	465	75	251	1918	38	18	<5		56
Grenville swarm diabase dike														
99RME-0138	561220	5169301	diabase		93	97	57	383	12290	7	19	33	0.6	59
Sudbury swarm diabase dikes														
99RME-0080	553945	5171343	diabase		77	89	58	57	16606	<5	<8	<8		
99RME-0137	561255	5169259	diabase		37	68	57	71	17805	<5	<8	<8		
99RME-0138	561220	5169301	diabase		93	97	57	383	12290	7	19	33	0.6	59
99RME-0237	556510	5171869	diabase		35	86	57	54	14988	<5	<8	<8		
99RME-0325	559490	5159224	diabase		51	80	62	35	19664	<5	<8	<8		
99RME-0337	556100	5169744	diabase		45	93	61	58	17745	<5	<8	<8		
99RME-2102	557953	5168109	fgr gabbro		65	87	56	71	18233	<5	<8	<8		
99RME-2104	557924	5168217	fgr gabbro		113	87	58	50	17552	<5	<8	<8		
99RME-2123	556898	5165694	gabbro	X	65	97	54	420	18585	17	18	<8		35
99RME-2178	558499	5166629	fgr gabbro		46	72	51	61	19664	<5	<8	<8		
99RME-2223	560650	5163984	gabbro		113	207	95	46	17745	<5	<8	<8		
99RME-2256	560135	5164659	fgr gabbro		65	89	54	58	17206	<5	<8	<8		
Matachewan swarm diabase dikes														
99RME-0031	559913	5174429	diabase		90	81	57	319	6894	7	38	72	0.5	117
99RME-4008	556033	5166763	diabase		52	64	51	157	7194	<5	16	17	0.9	33
99RME-2118	556604	5166763	diabase		52	66	47	143	7194	6	18	15	1.2	39

Appendix 5. —continued.

Sample number	UTM 17T, NAD 83		Field Rock Name	Visible Sul phide	Cr (4)	Ni (5)	Co (5)	Cu (5)	Ti (3)	Au (5)	Pt (8)	Pd (8)	Pt/Pd	Au+ Pt+ Pd
	Easting	Northing			ppm					ppb				
Crerar 1 (Tomrose, Occurrence 8, Map P.3432)														
99RME-0536	558410	5160369	gabbro	X	261	712	168	1019	5560	<5	<8	<8		
99RME-0537	558410	5160409	leucogabbro	X	596	247	44	21	437	<5	<8	<8		
99RME-0538	558410	5160394	oxide rock	X	436	477	162	688	4247	77	<8	<8		77
99RME-0539	558410	5160384	oxide rock		411	323	132	287	7581	<5	<8	<8		
99RME-0540	558410	5160379	leuconorite	X	138	422	58	21	287	<5	<8	<8		
99RME-0541	558410	5160374	leuconorite	X	518	393	79	372	783	<5	<8	<8		
99RME-0582	558500	5160444	gabbro	X	257	248	41	243	890	8	24	38	0.6	70
Crerar 2 (stripped area 135 m west of Tomrose)														
99RME-0530	558545	5160474	norite	X	299	303	53	308	698	18	78	261	0.3	357
99RME-0531	558545	5160474	leuconorite		330	160	35	26	708	<5	<8	<8		
99RME-0532	558545	5160474	pyroxenite		431	219	54	45	718	<5	54	76	0.7	130
99RME-0533	558545	5160474	leuconorite		329	190	47	39	867	<5	<8	<8		
99RME-0534	558545	5160474	oxide layer	X	600	634	117	550	998	<5	<8	<8		
Crerar 3 (Historic trench, Occurrence 1, Map P.3432)														
99RME-0571	559525	5160984	oxide rock	X	218	444	144	2010	3167	<5	9	<8		9
99RME-0572	559525	5160984	oxide rock	X	377	278	107	1666	4219	<5	<8	<8		
99RME-0573	559525	5160984	gabbro		272	151	41	20	730	<5	<8	8		8
99RME-0574	55952	5160984	gabbro	X	300	363	134	616	2735	20	<8	<8		20
Crerar 4 (new occurrence)														
99RME-0576	559725	5160809	gabbro	X	356	297	92	1408	3857	<5	36	17	2.1	53
99RME-0577	559725	5160809	gabbro	X	227	122	51	706	4452	11	35	36	1.0	82
Crerar 5 (Occurrence 2, Map P.3432)														
99RME-0642	559125	5162019	mafic gneiss	X	16	65	52	7354	N.A.	152	24	29	0.8	205
99RME-0643	559125	5162019	mafic gneiss	X	12	38	34	5008	N.A.	81	7	9	0.8	97
99RME-0644	559125	5162019	mafic gneiss		7	49	39	282	N.A.	6	17	20	0.9	43
99RME-0645	559125	5162019	mafic gneiss	X	24	38	27	2650	N.A.	30	24	66	0.4	120
99RME-0646	559125	5162019	mafic gneiss	X	<4	37	24	7833	N.A.	191	70	322	0.2	583
Crerar 6 (Occurrence 3, Map P.3432)														
99RME-0654	559160	5161994	mafic gneiss	X	28	126	66	5063	N.A.	97	435	315	1.4	847
99RME-0655	559160	5161994	mafic gneiss		50	84	38	21	N.A.	<5	9	<8		9
Crerar 7 (Occurrence 4, Map P.3432)														
99RME-0650	558875	5162184	mafic gneiss	X	17	45	18	8094	N.A.	92	<8	<8		92
99RME-0651	558875	5162184	mafic gneiss	X	63	94	38	64	N.A.	<5	<8	<8		
Crerar 8 (new occurrence)														
99RME-0676	557560	5159534	mafic rock		325	173	71	439	N.A.	7	405	298	1.4	710
99RME-0676-#2	557560	5159534	mafic rock		N.A.	179	69	385	N.A.					
99RME-0679	558060	5159759	oxide gabbro	X	280	486	96	1942	N.A.	90	581	443	1.3	1114

Appendix 5. —continued.

Sample number	UTM 17T, NAD 83		Field Rock Name	Visible Sulphide	Cr (4)	Ni (5)	Co (5)	Cu (5)	Ti (3)	Au (5)	Pt (8)	Pd (8)	Pt/Pd	Au+ Pt+ Pd
	Easting	Northing			ppm					ppb				
Crerar 9 (new occurrence)														
99RME-0542	557690	5159584	oxide rock	X	367	519	126	2054	1607	<5	<8	<8		
99RME-0542-#2	557690	5159584	oxide rock	X	N.A.	524	126	2378	N.A.	N.A.	N.A.	N.A.		
99RME-0544	557575	5159583	oxide rock	X	461	192	78	534	3116	29	<8	<8		29
99RME-0544-#2	557575	5159583	oxide rock	X	N.A.	193	75	637	N.A.	N.A.	N.A.	N.A.		
99RME-0545	557575	5159583	Melanogabbro		696	278	109	514	4122	7	<8	<8		7
99RME-0545-#2	557575	5159583	Melanogabbro		N.A.	215	90	108	N.A.	N.A.	N.A.	N.A.		
99RME-0675	557585	5159534	mafic rock	X	268	158	59	172	N.A.	<5	<8	<8		
99RME-0790	557575	5159583	mafic rock		N.A.	171	72	517	N.A.	5	60	52	1.2	117
99RME-0791	557575	5159583	mafic rock		N.A.	136	63	1011	N.A.	6	83	61	1.4	150
99RME-0792	557575	5159583	mafic rock		N.A.	422	110	1946	N.A.	17	224	68	3.3	309
99RME-0793	557575	5159583	mafic rock		N.A.	460	131	1726	N.A.	13	139	50	2.8	202
Crerar 10 (new occurrence)														
99RME-0504	555190	5160664	leucogabbro		29	53	39	21	4495	76	157	124	1.3	357
99RME-0505	556740	5160764	leucogabbro		54	45	41	89	6113	121	129	156	0.8	406
Non-mineralized River Valley intrusion samples, Crerar Twp., south of Sturgeon River														
99RME-0399	556295	5160747	melanonorite		109	714	133	42	1259	<5	<8	12		12
99RME-0454	557775	5161123	leuconorite		439	139	41	26	1379	<5	<8	<8		
99RME-0459	557550	5161363	melanonorite		90	629	128	40	840	<5	10	8	1.3	20
99RME-0463	556895	5161233	gabbroic anothosite		12	38	30	15	3657	<5	<8	21		21
99RME-0664	557290	5159744	gabbronorite	X	105	34	12	38	N.A.	<5	<8	<8		
99RME-0667	556800	5159564	gabbro	X	7	30	12	220	N.A.	5	15	14	1.1	34
99RME-0740	556777	5163524	gabbro		140	57	28	107	1791	10	<8	<8		10

Sample number	Easting	Northing	Field Rock Name	Visible Sulphide	Cr (4)	Ni (5)	Co (5)	Cu (5)	Ti (3)	Au (6)	Pt (1)	Pd (2)	Pt/Pd	Au+ Pt+ Pd
Henry and Loughrin Township Samples														
02RME-0003	552146	5160878	rusty tonalite gneiss	X	59	24	21	32	N.A.	<6	<1	<2		
02RME-0141	535130	5152885	oxide gabbro		98	180	94	469	N.A.	7.1	6.2	4.5	1.4	10.7
02RME-0315	546386	5158749	gabbronorite		698	162	47	42	N.A.	<6	8.5	6.9	1.3	15.4
02RME-0369	546960	5158730	vein cuts Loughrin Lake body	X	25	19	<5	52	N.A.	<6	<1	<2		
02RME-2282	539745	5162400	vein cuts Loughrin Lake body	X	438	55	24	35	N.A.	<6	5.3	3.9	1.4	9.2
02RME-2299	538913	518845	hornblendite		642	321	98	81	N.A.	<6	17.8	13.9	1.3	31.7

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.